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SURVEY OF CHEMICAL FACTORS IN SAGINAW BAY (LAKE HURON)

by

V. E. Smith, K. W. Lee, J. C. Filkins,
K. W. Hartwell, K. R. Rygwelski and
J. M. Townsend
Cranbrook Institute of Science
Bloomfield Hills, Michigan 48013

Grant No. R802685

Project Officer

Victor J. Bierman, Jr.
Environmental Research Laboratory--Duluth
Large Lakes Research Station
Grosse Ile, Michigan 48138

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
DULUTH, MINNESOTA 55804

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FOREWORD

Our nation's freshwaters are vital for all animals and plants, yet our diverse uses of water---for recreation, food, energy, transportation, and industry---physically and chemically alter lakes, rivers, and streams. Such alterations threaten terrestrial organisms, as well as those living in water. The Environmental Research Laboratory in Duluth, Minnesota develops methods, conducts laboratory and field studies, and extrapolates research findings

--to determine how physical and chemical pollution affects aquatic life

--to assess the effects of ecosystems on pollutants

--to predict effects of pollutants on large lakes through use of models

--to measure bioaccumulation of pollutants in aquatic organisms that are consumed by other animals, including man

This report contains the results of an intensive sampling and analysis program on Saginaw Bay, Lake Huron. These results were used to establish baseline water quality in the bay and to develop mathematical simulation models which describe the effects of pollutant inputs. Of particular concern in the present study are the excessive inputs of phosphorus and nitrogen to Saginaw Bay and the resulting overproduction of algal biomass.

Donald I. Mount, Ph.D.
Director
Environmental Research Laboratory
Duluth, Minnesota

PREFACE

Water quality factors in Saginaw Bay have been surveyed several times during the past 40 years. While the present study is by no means definitive, it represents a much more comprehensive effort - in time, space and variety of parameters - than any previous survey. This was necessary for two reasons: to establish a current information base by which the effect of future reduced loadings to the bay can be judged; and to support on-going EPA modeling programs that deal with the relationships between nutrient levels and plankton populations. This survey is continuing at a somewhat reduced level in further support of the modeling effort. The results of the past two years of monitoring have impressed us with the changeable nature of Saginaw Bay and the consequent need to extend the survey over several years in order to distinquish genuine trends from annual fluctuations in water quality. In principle, at least, the bay resembles a shallow estuary in which strong chemical gradients and mixing occur, and where wind stress causes periodic tide-like changes in water level. These features, combined with climatic variations from year to year, greatly complicate the problem of defining "base-line" water quality in Saginaw Bay.

We emphasize the fact that our field work has been coordinated whenever practical with other concurrent studies on the bay. In particular, our sampling coincided with satellite monitoring which was the subject of a separate investigation on the use of remote sensing as a tool in water quality surveying. While this scheduling created some problems with weather and personal convenience, it resulted in a body of correlated data that is available for detailed study. Initial work on two sets of Landsat data has already been published and the results were summarized briefly in this report (Cooperative Studies, Section 8). Similar possibilities exist for correlated studies of water chemistry and plankton populations which were sampled concurrently by University of Michigan grantees.

A final comment concerning our presentation of the data is appropriate. For reasons of economy and convenience we have grouped and averaged the data somewhat arbitrarily (i.e., by quarter and segment), even though this process confers some statistical bias on the results. Some such condensation of the data was necessary, however, in order to view the results in a comprehensible form. We readily admit that some other method of summarizing the data might well support other interpretations of variance and distributional patterns for certain parameters. At any rate, the raw data are available from the EPA STORET system.

ABSTRACT

Water quality in Saginaw Bay, Michigan (western Lake Huron) was surveyed during 32 cruises in 1974 and 1975, as part of the International Joint Commission's Upper Lakes Reference Study co-sponsored by the United States and Canada. Goals of the study were to establish a base of water quality information and to provide data required to model biological and hydrological processes in the bay. Sampling and in situ monitoring were conducted at 18-day intervals during April - October (coinciding with Landsat satellite passes) and approximately at monthly intervals during November - March. Samples were collected from several depth levels at 59 stations in 1974 and at a 37-station subset of these 59 stations in 1975. Measurements included: temperature, dissolved oxygen, conductivity, chloride, pH, alkalinity, Secchi depth, chlorophylls, nitrate and phosphate, organic nitrogen, total phosphorus, organic carbon, total solids and major metals. Additional diurnal or daily sampling was conducted at selected stations. Samples were analyzed aboard ship or at the EPA Large Lakes Research Station at Grosse Ile, Michigan.

Findings, based on statistical analyses of the data (filed in STORET), indicate that highly eutrophic waters, in the inner part of Saginaw Bay undergo complex mixing with oligotrophic Lake Huron waters in the outer bay. Comparisons with 1956 data show diminished levels of certain parameters. Remote sensing was shown to be useful for extrapolating water quality to unsampled areas on a survey-by-survey basis.

The resulting data base will be used in formulating future policies for pollution abatement in Saginaw Bay and adjoining waters.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

APHA -- American Public Health Association
CCIW -- Canadian Centre for Inland Waters
CIS -- Cranbrook Institute of Science
ERTS -- Earth Resources Technology Satellite (now Landsat)
FWPCA -- Federal Water Pollution Control Administration
FWS -- Fish and Wildlife Service
GLBC -- Great Lakes Basin Commission
GLRD -- Great Lakes Research Division of University of Michigan
LLRS -- Large Lakes Research Station of EPA at Grosse Ile, Michigan
LSC -- Lake Survey Center
MSCC -- Michigan Stream Control Commission
MWRC -- Michigan Water Resources Commission, Department of Natural Resources, State of Michigan
NAS/NAE -- National Academies of Science/Engineering
NASA -- National Aeronautics and Space Administration
NOAA -- National Oceanographic and Atmospheric Administration
PAMILA -- Peak Analysis for Multi-Instrument Lab Automation
SPSS -- Statistical Package for the Social Sciences
STORET -- EPA's computer data file
d. O_2 -- dissolved oxygen
sp. cond. -- specific conductivity
f. Cl. -- filtered chloride
tot. alk. -- total alkalinity
nf. chl. *a* -- non-filterable chlorophyll *a* (corrected chlorophyll a)
u. org. C -- unfiltered organic carbon
f. org. C -- filtered organic carbon
u. tot. sol. -- unfiltered total solids
f. reac. SiO_2-Si -- filtered reactive silicate-silicon
f. tot. NH_3-N -- filtered total ammonia-nitrogen
f. NO_3 + NO_2-N -- filtered nitrate + nitrite-nitrogen
u. Kjel. N -- unfiltered Kjeldahl nitrogen
tot. N -- total nitrogen (u. Kjel. N + f. NO_3 + NO_2-N)
f. reac. PO_4-P -- filtered reactive phosphate-phosphorus
f. tot. P -- filtered total phosphorus
u. tot. P -- unfiltered total phosphorus
u. Na -- unfiltered sodium
u. K -- unfiltered potassium
u. Ca -- unfiltered calcium
u. Mg -- unfiltered magnesium

calc. part. P -- calculated particulate phosphorus (u. tot. P - f. tot. P)

calc. f. inorg. N -- calculated inorganic nitrogen (f. NO_3 + NO_2- N + f. tot. NH_3)

calc. f. org. P -- calculated organic phosphorus (f. tot. P - f. reac. PO_4-P)

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SECTION 1

INTRODUCTION

This survey was conducted as part of the International Joint Commission's (IJC) Upper Lakes Reference Study of Lake Huron and Lake Superior. Our spatial coverage of Saginaw Bay overlapped slightly that of Southern Lake Huron and Northern Lake Huron - Georgian Bay, areas surveyed respectively by the University of Michigan and the Canada Centre for Inland Waters. U.S. and Canadian interest in Saginaw Bay is related to the possible impact of bay pollution on Lake Huron waters on both sides of the international boundary.

The work described here was closely coordinated with other related studies of Saginaw Bay. Phytoplankton and zooplankton were surveyed concurrently at the same stations by EPA grantees at the University of Michigan (Great Lakes Research Division and Biological Station, respectively). Current meter and drogue studies were conducted during summer 1974 by the National Oceanic and Atmospheric Administration (Lake Survey Center). Experiments on multispectral remote measurment of chlorophyll were carried out during spring and summer 1974 by the National Aeronautics and Space Administration (Lewis Research Center). Finally, nearly all cruises coincided with Landsat (ERTS) satellite passes over Saginaw Bay, to provide ground truth for a NASA-supported study of remote sensing carried out by Bendix Aerospace Systems Division.

Concurrent data on nutrient inputs from the bay's major tributaries were collected by the Michigan Department of Natural Resources (Water Management Division). Additional samples were collected at four stations by the Dow Chemical Company (Bay City) and municipal water intake plants at Bay City, Pinconning and Whitestone Point.

Most of these results are being incorporated in some fashion into mathematical models under development at the EPA Large Lakes Research Station, Grosse Ile, Michigan. Our approaches to sampling the bay and organizing the data throughout this study were designed primarily to support the modeling programs. The statistical results presented here are not intended to provide necessarily the most objective view of water quality in Saginaw Bay, but rather are offered as a convenient summary of the data and their interrelationships.

SECTION 2

CONCLUSIONS

These results support the general findings of earlier studies that Saginaw Bay is estuarine in character with pronounced gradients of water quality between inner and outer bay, high primary production, active circulation and frequent water level changes induced by wind stress. Water quality ranges from eutrophic near the Saginaw River mouth to oligotrophic in the bay mouth. The data suggest that thermal stratification occurs only briefly during early spring, except in deep waters of the outer bay where a thermocline persists throughout the summer.

Earlier assertions that the prevailing circulation of Saginaw Bay is counterclockwise may be over-simplified, since current patterns are highly dependent on wind stress. However, mean values of most parameters are higher along the eastern side of the bay, suggesting that river water exits the bay mainly on that side. Similar evidence points to a greater influx of Lake Huron water along the western side of the bay. Additionally, nutrient concentrations on the eastern side may be augmented to an important degree by runoff and resuspension of sediments.

Saginaw River water is traceable throughout the bay by conservative features such as chloride, conductivity, and major metals. Since concentrations of these factors are related to overall turbidity and water color, it is feasible to map their distribution (i.e., that of Saginaw River water) using multispectral satellite (Landsat) data and correlation analysis. However, the empirical relationships between satellite and water quality data are influenced by atmospheric and other variables and therefore must be re-defined on each occasion.

The data indicate a significant decrease in levels of most parameters since 1965 surveys, especially within the inner bay. Presumeably, this is due mainly to a decrease in nutrient input rates over this period. However, a similar but smaller decrease in levels from 1974 to 1975 may be due to climatic differences: e.g., more precipitation and runoff during 1974.

The Saginaw River system continues to have an adverse effect on water quality in the bay, although no parameter values were consistently in violation of EPA or Michigan standards for ammonia, chloride, dissolved oxygen, nitrate-nitrite or pH. An eightfold increase in chlorophyll *a* concentrations from the outer to inner bay indicates the extent of nutrient enrichment, largely from the Saginaw River.

SECTION 3

RECOMMENDATIONS

In view of the difficulty of defining baseline conditions in a system as variable as Saginaw Bay, another intensive survey of the present type should be conducted after a 5-10 year interval. From a management standpoint, this is all the more critical because waste treatment processes are being upgraded throughout the Saginaw River basin and because productivity models currently under development will require testing and verification on independent sets of field data as water quality values change over time.

Future surveys in support of modeling efforts should include daily monitoring of major nutrient inputs from the Saginaw River and other tributaries. Other contributions of nutrients to bay waters from the atmosphere and from resuspended sediments should be assessed more thoroughly than in this study. Our results have indicated a need to take stock of infrequent but substantial inputs of nutrients that may occur during storms or periods of high runoff. The variability of some parameters at certain stations and times is complex and should be investigated further as to cause and effect.

Survey vessels should carry out continuous monitoring of at least two parameters, percent transmittance and specific conductivity, in order to locate water mass boundaries and define the slope of chemical gradients. This information, together with sample and satellite data, could be used to map certain parameter distributions throughout the bay.

Other statistical relationships should be defined between chemical parameters and such variables as phytoplankton and zooplankton biomass. Such results would be informative as to the varying effects of these nutrients on biota in the water column.

Since the selection of sampling stations on Saginaw Bay was not random, the present mean data for each bay segment should be compared to random data sets generated by contouring, or to data corrected for depth by volume averaging.

SECTION 4

BACKGROUND

Saginaw Bay is a broad estuary extending southwestward from Lake Huron's western shore (Figure 1). The dimensions of the bay are approximately 42 x 82 km (26 x 51 mi); it covers an area of some 2,960 km^2 (1,143 mi^2). The inner and outer halves of the bay, divided roughly by a line between Sand Point and Point Lookout (Figure 2), have mean depths of 4.6 m (15 ft) and 14.6 m (48 ft), and each half contains some 30% and 70% of the total water volume, respectively. The sediments are mainly glacial deposits of sand, cobble, clay or silt. The shoreline topography is generally low and varies from marsh to sand beaches and occasional rocky outcrops.

The Saginaw River and tributaries, which empty into the extreme southwestern end of the bay, drain a watershed of approximately 21,000 km^2 (8,000 mi^2). Land use in this area is dominated by agriculture and secondly, by native forest. However, the basin had an estimated population in 1970 of 1,235,920, and includes four major urban-industrial centers: Bay City, Midland, Saginaw and Flint. These have had a profound impact on water quality of the Saginaw River system and thus on Saginaw Bay. These and other features of the bay environment were reviewed by Freedman (1974). Table 1 gives a summary of morphometric data for the bay, its watershed and areal subdivisions, as established in the present study. For purposes of this discussion the outer limits of the bay are defined on the map by a line connecting the base of Tawas Point on the west with the tip of Pointe aux Barques on the east (see Figure 11).

Saginaw Bay, due to its high surface/volume ratio and broad communication with Lake Huron, is readily influenced by climatic variables including temperature, light, wind and wave stress and by local currents in Lake Huron. A typical sequence of seasonal changes in the bay, as occurred during February - July 1975, is seen in Landsat (satellite) imagery, Figures 3 - 7. Often there is active mixing of water masses having strikingly different charateristics (Figure 8), especially during periods of high runoff. Although circulation within the bay is rapid and highly variable, the predominant pattern has been reported to be counter-clockwise: oligotrophic Lake Huron water enters along the northwestern shore and eutrophic bay water exits along the northeastern side (Freedman, 1974). Rapid changes in water level (i.e., seiches) of up to two meters are associated mainly with strong southwest or northeast winds during summer and fall, respectively. The inner bay is largely frozen over during January - February (Figure 3). Wave action

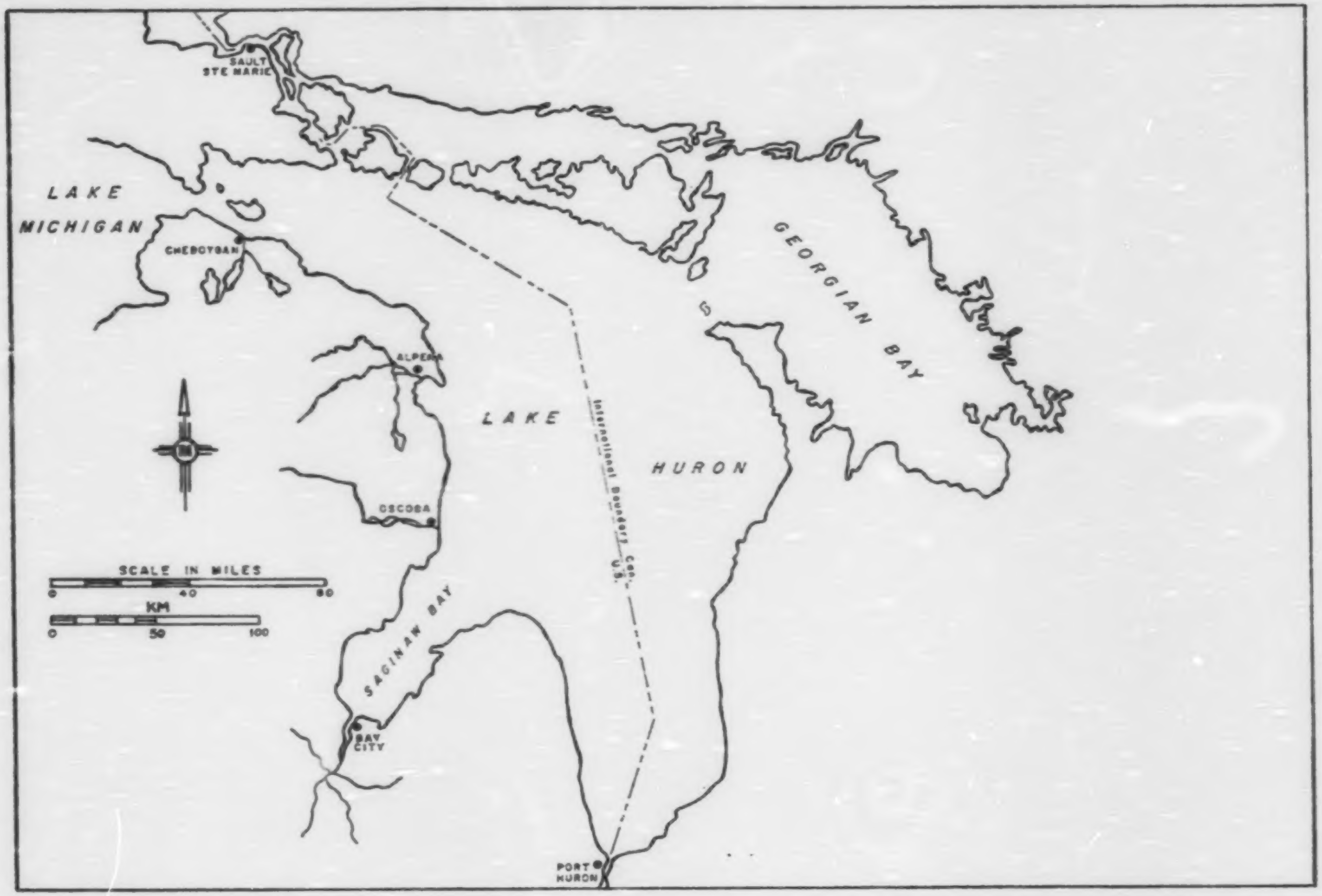
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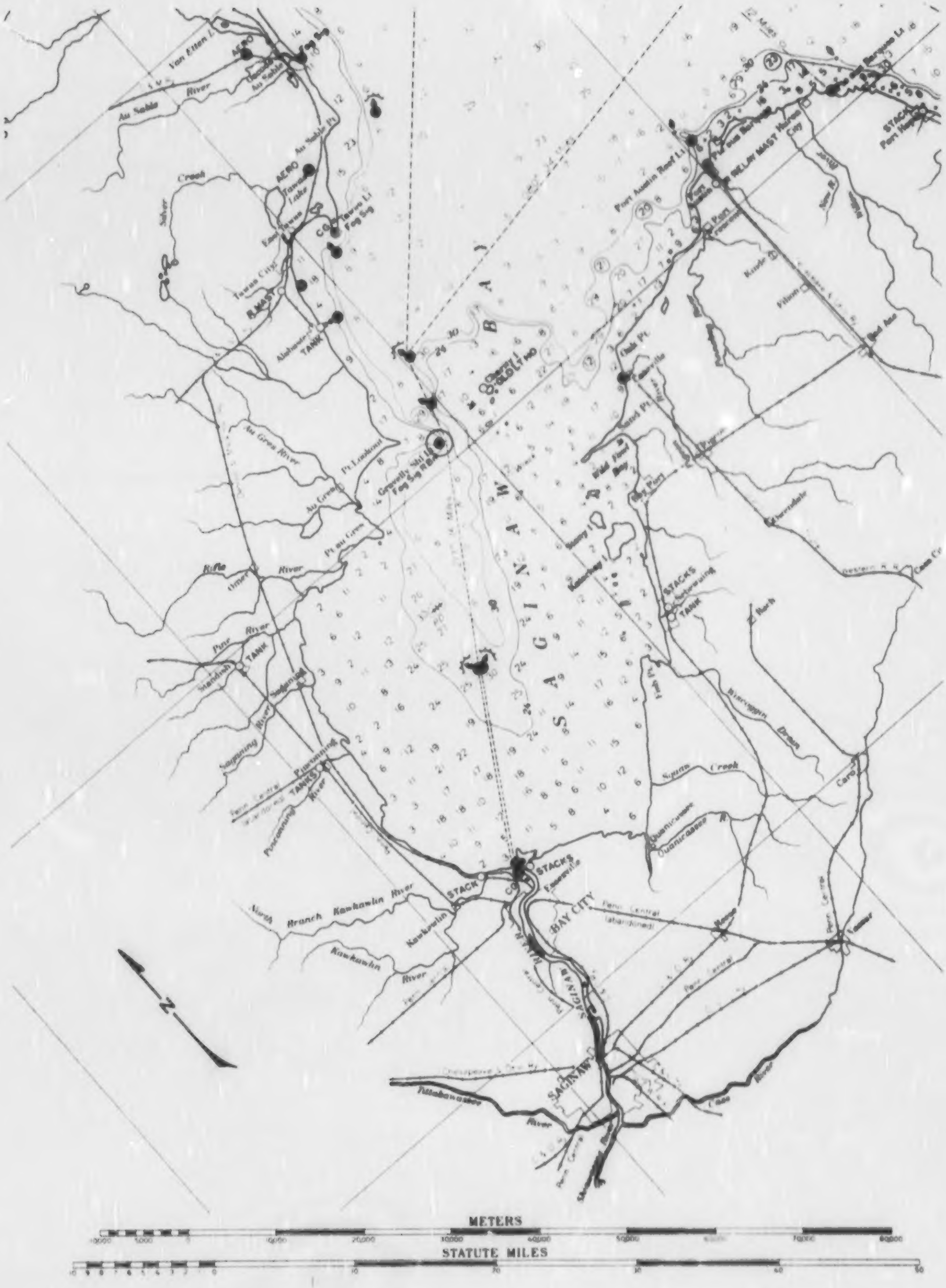
Figure 1. Lake Huron, including Saginaw Bay.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Sebewaing
Bay Port
Wild Fowl Bay
Caseville
Oak Pt.
Port Austin Reef Lt.
Port Austin
Bad Axe
N
METERS
STATUTE MILES

Figure 2. Saginaw Bay and environs (NOAA Chart No. 5, Lake Huron, 1974).

TABLE 1. SUMMARY OF MORPHOMETRIC DATA FOR SAGINAW BAY AND ENVIRONS

Watershed:

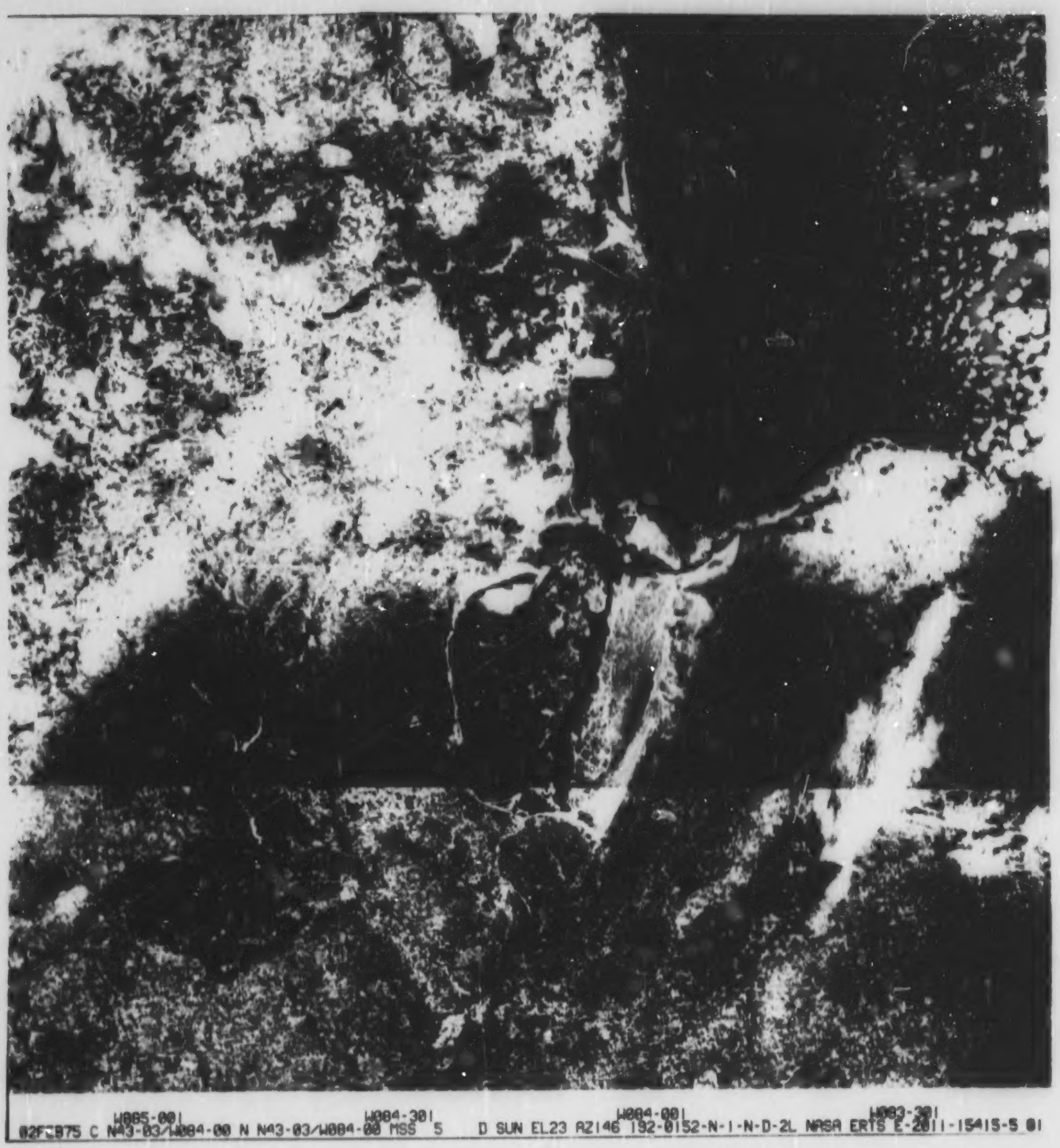
Total area (km^2) 21,000
Tributaries, mean input (m^3/sec) 153.7

Whole Bay:

Total area (km^2) 2,960
Total volume (m^3) 30×10^9
Lengh of shoreline (km) 240
Mean depth: inner bay (m) 4.6
outer bay (m) 14.6
Max. depth: inner bay (m) 14.0
outer bay (m) 40.5

Model Segments:

	Mean Depth (m)	Max. Depth (m)	Surface Area (m^2)	Volume (m^3)	Surface/ Volume Ratio
Seg. 1	3.14	7.92	276×10^6	866×10^6	.32
Seg. 2	6.37	15.11	860×10^6	548×10^7	.16
Seg. 3	2.85	5.79	412×10^6	117×10^7	.35
Seg. 4	11.40	26.82	648×10^6	736×10^7	.09
Seg. 5	13.10	34.44	676×10^6	883×10^7	.08



W085-001
W084-301
W084-001
W083-301
02FEB75 C N43-03/W084-00 N N43-03/W084-00 MSS 5 D SUN EL23 AZ146 192-0152-N-1-N-D-2L NASA ERTS E-2011-15415-5 01

Figure 3. Landsat-2 image (band 5) of February 2, 1975.

Note: An unusually mild winter resulted in broken ice cover (light areas) over the bay's lower two-thirds. In 1974 the same area was completely frozen at this time. A bar of thinner ice stretches northward along the Lake Huron shore.

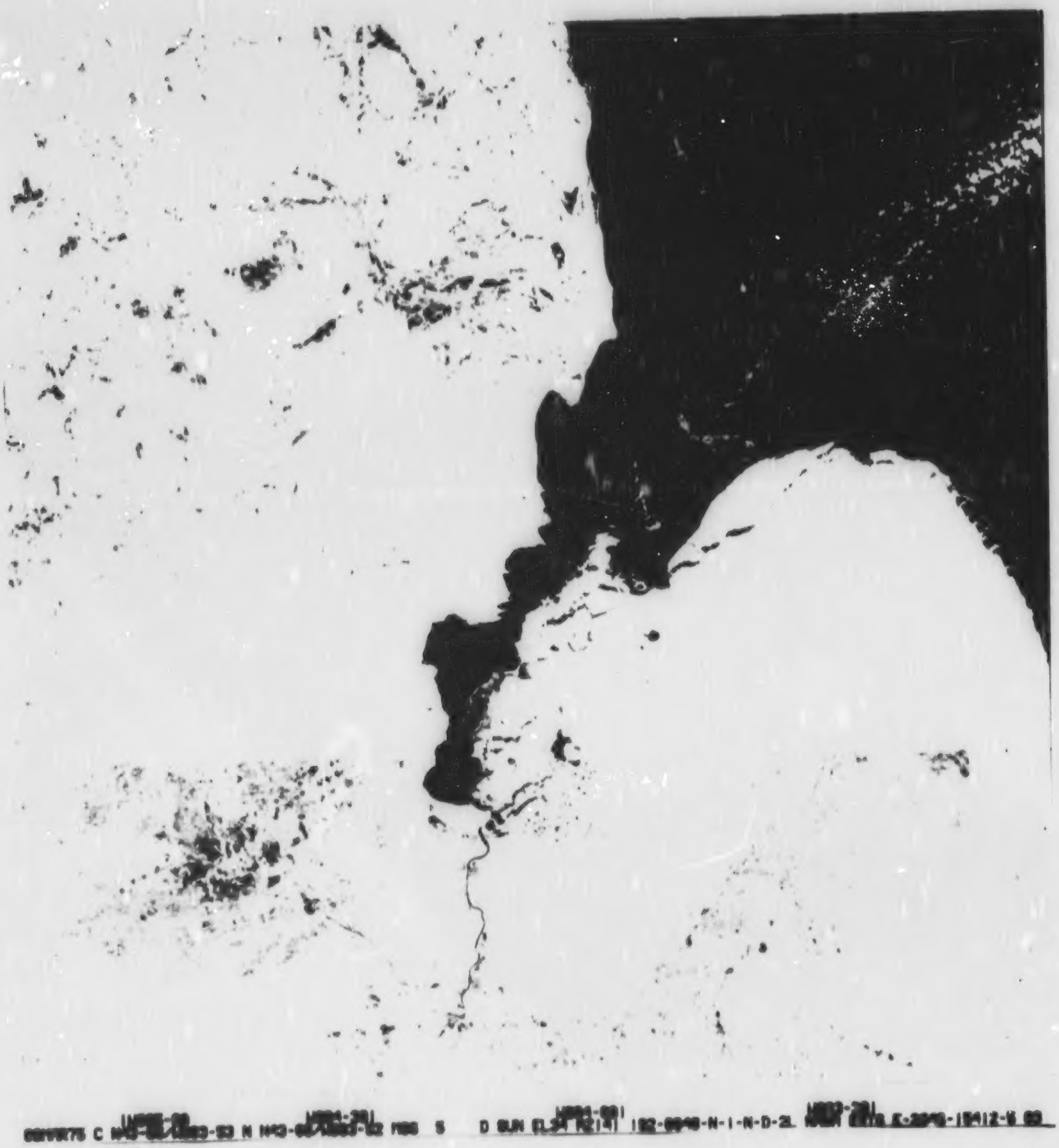
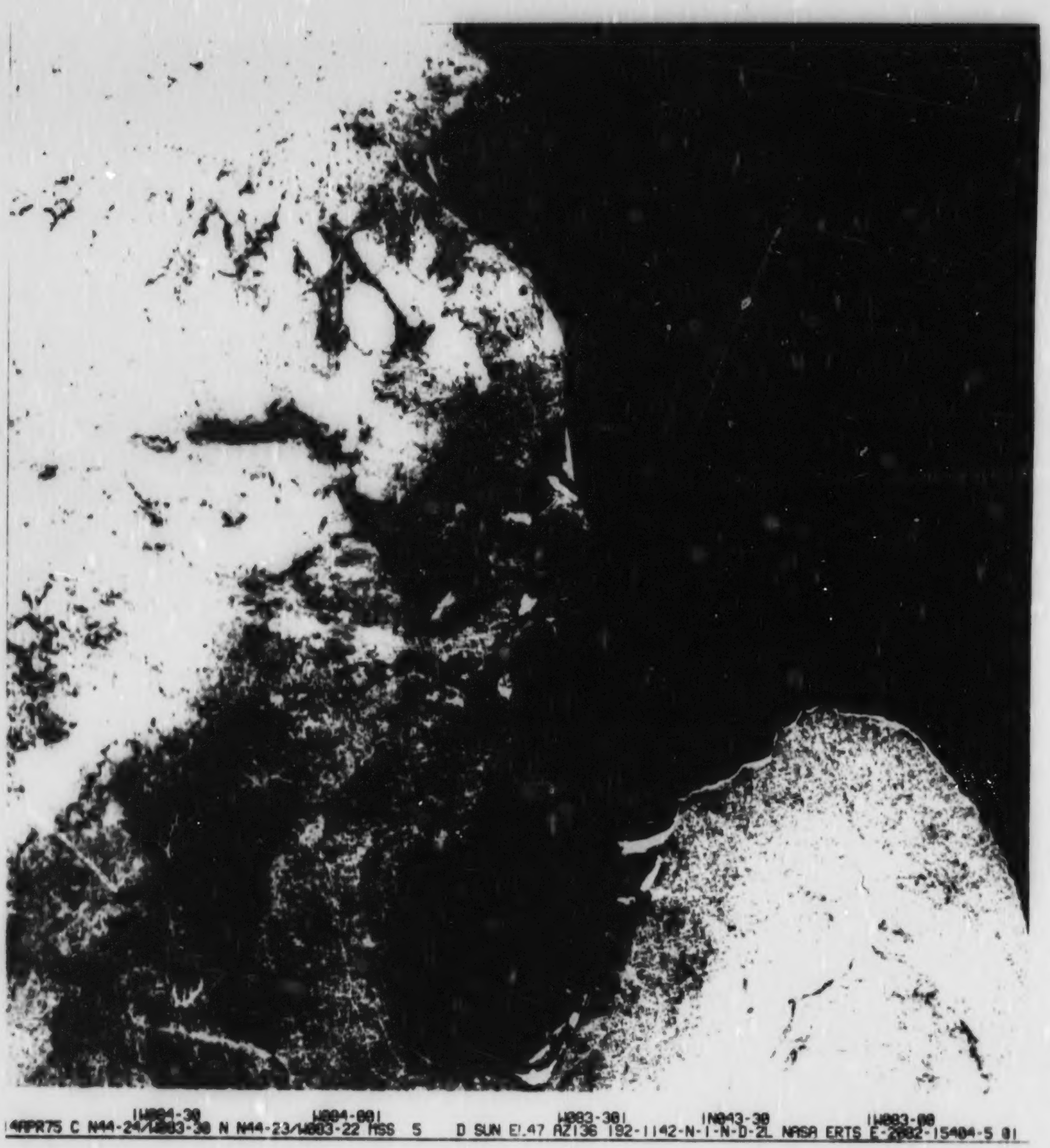


Figure 4. Landsat-2 image (band 5) of March 9, 1975.

Note: Fresh snow covers the ice pack, which has shifted considerably since the previous scene. The patch of open water near the Saginaw River mouth (lower center) is maintained all winter by heated discharge from the Karn-Weadock power plant (Consumers Power Company).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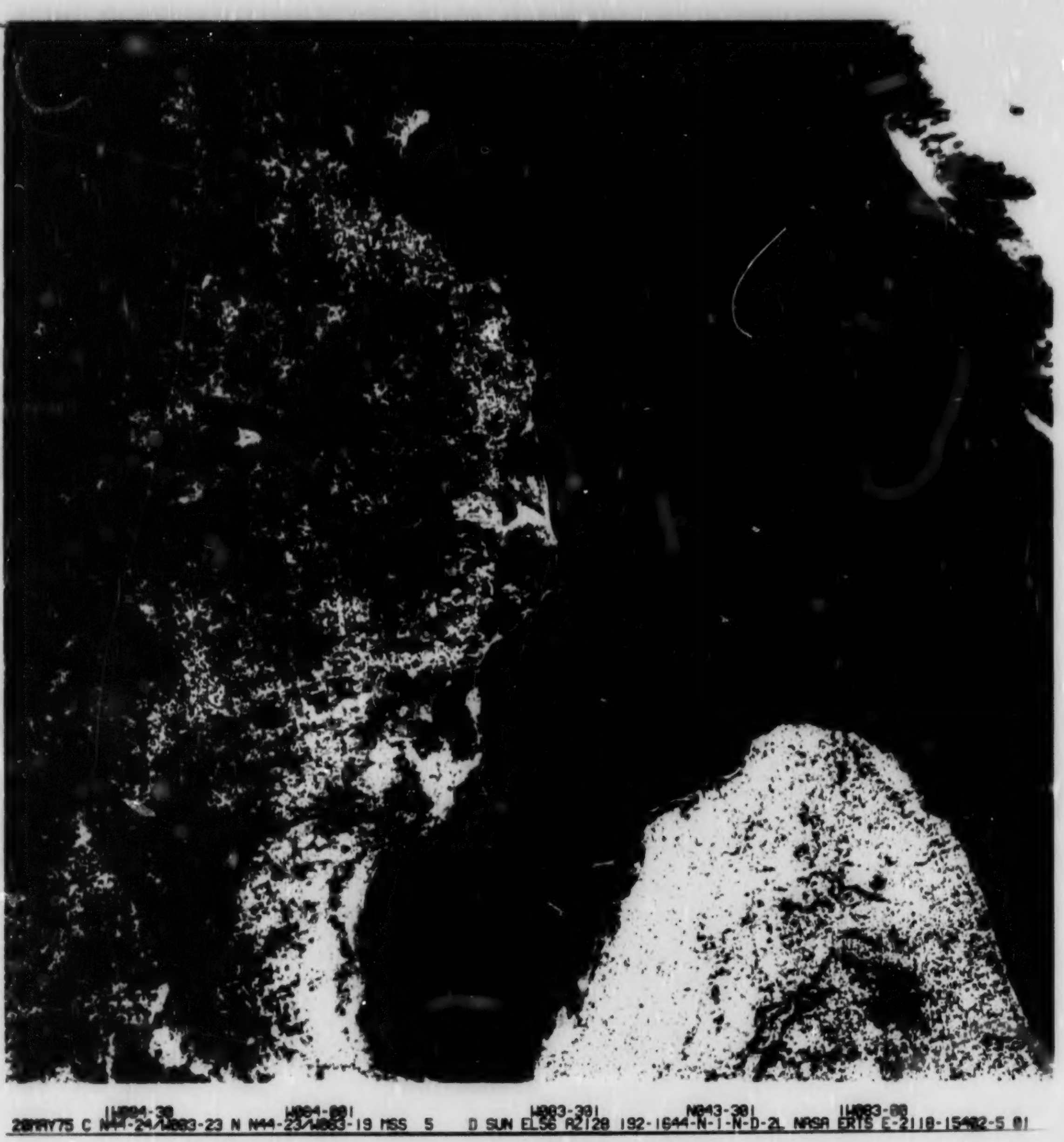
W084-00
W083-30
N043-30
W083-00
14APR75 C N44-24/W083-30 N N44-23/W083-22 MSS 5 D SUN EL47 AZ136 192-1142-N-1-N-D-2L NASA ERTS E-2082-15404-5 01

Figure 5. Landsat-2 image (band 5) of April 14, 1975.

Note: The bay is nearly ice-free by this date except for shelfs along the eastern shore. Turbidity plumes (lighter waters) are seen emerging from the Saginaw River during this period of thawing and high runoff. A late snowfall covers the land.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W084-00
W083-30
N043-30
W083-00
20MAY75 C N44-24/W083-23 N N44-23/W083-19 MSS 5 D SUN EL56 AZ128 192-1644-N-1-N-D-2L NASA ERTS E-2118-15402-5 01

Figure 6. Landsat-2 image (band 5) of May 20, 1975.

Note: Following the spring runoff, turbidity has diminished except in inshore areas. The bay's islands are clearly outlined against the darker water.

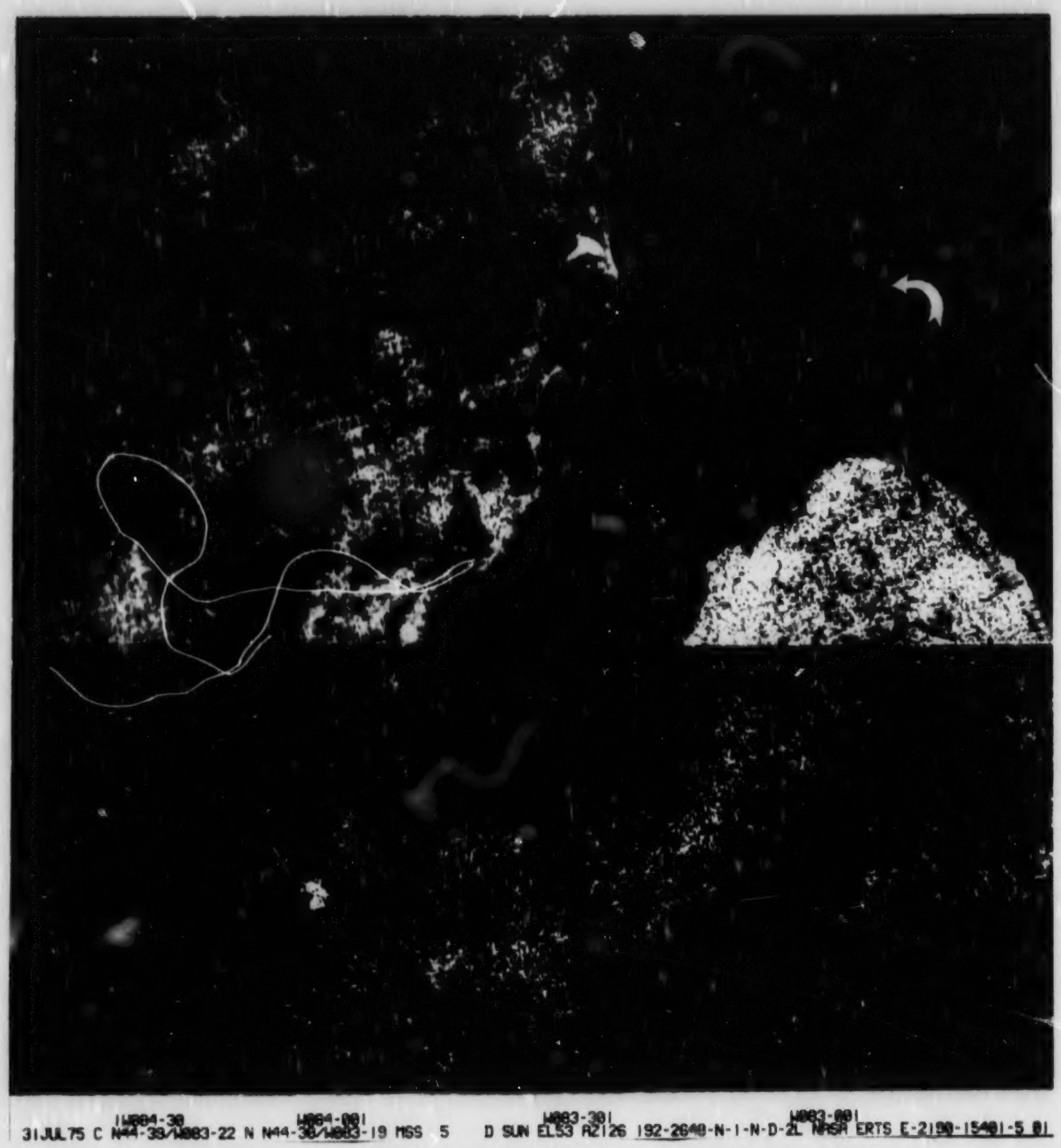

W084-30
W084-001
W083-301
W083-001
31JUL75 C N44-38/W083-22 N N44-38/W083-19 MSS 5 D SUN EL53 AZ126 192-2640-N-1-N-D-2L NASA ERTS E-2190-15401-5 01

Figure 7. Landsat-2 image (band 5) of July 31, 1975.

Note: Sharp boundaries between water masses indicate an intrusion of clear (darker) Lake Huron water along the outer bay's western side. Turbid (lighter) bay waters are concentrated along the eastern shore and form a gyre far out in Lake Huron (arrow). This may typify a prevailing pattern of counter-clockwise circulation in Saginaw Bay.

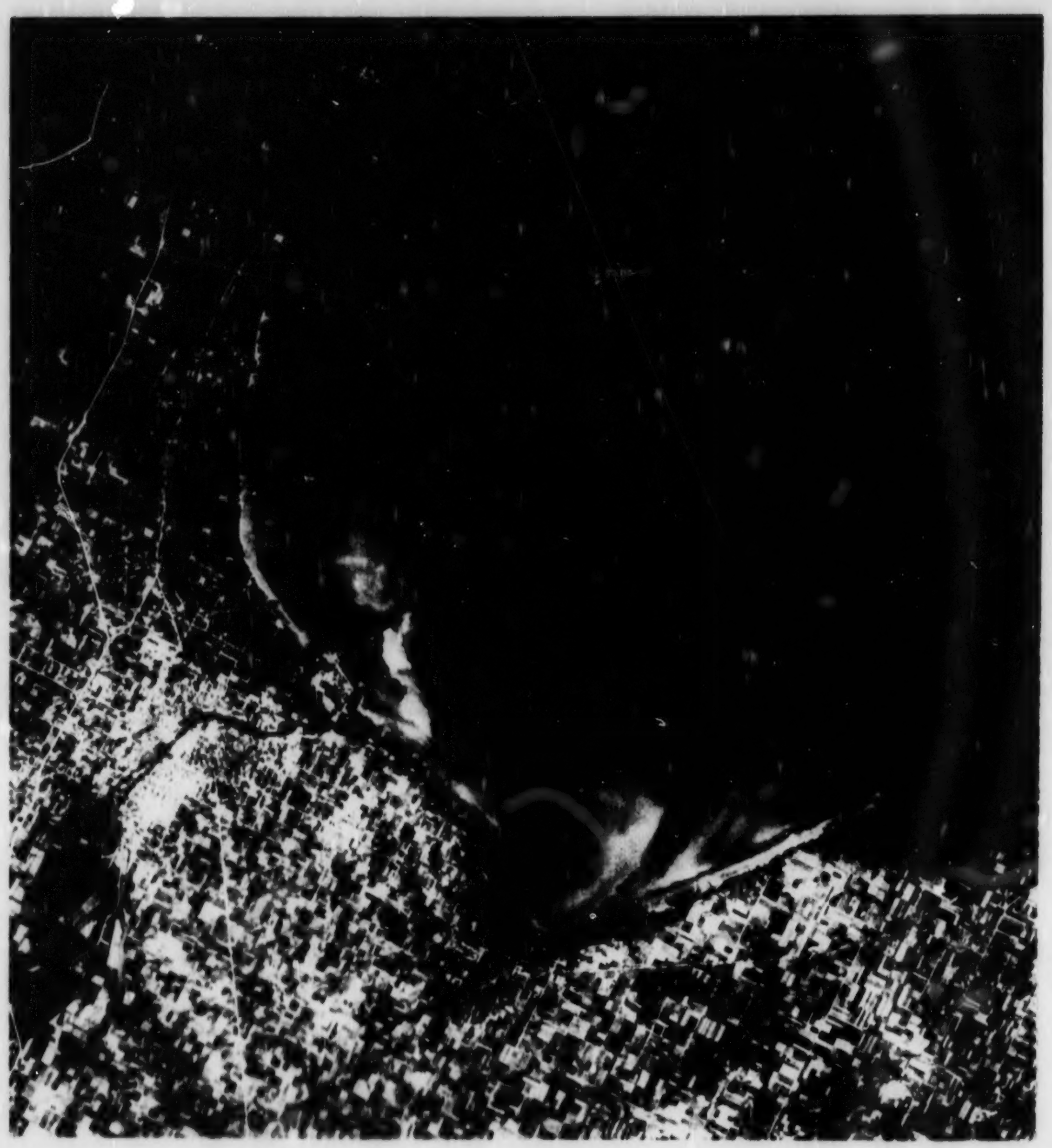


Figure 8. Skylab S-190B photograph of September 18, 1974.

Note: Details of turbidity patterns are readily seen in a color photograph of lower Saginaw Bay. Mixing of dark brown river water with clearer with clearer blue waters of the open bay has evidently resulted in these plumes of highly reflective (lighter) water. Some turbidity inshore may be wind-generated.

strongly affects the resuspension of shallow water sediments in the inner bay. Dynamic features of the bay's hydrology as described by water quality and circulation models will be discussed in detail elsewhere in this Research Series.

The history of Saginaw Bay water quality has been documented by a number of surveys, chiefly those listed in Table 2. Some results of these are summarized in Freedman (1974). The present survey, begun in October 1973, represents the most comprehensive study of water chemistry in Saginaw Bay to date. Indications are that the study period embraces two years that are significantly different as to climatic and hydrological factors (Figures 9, 10; Table 7). These conditions would be expected to create seasonal water quality differences that are not necessarily related to long term trends.

Historically, pollution and eutrophication in Saginaw Bay have had an adverse impact, direct or otherwise, on the bay's natural potential to support a diversified fishing industry, large populations of migratory waterfowl, and to provide domestic water supplies as well as recreational and esthetic uses (USFWS, 1969; GLBC, 1975; Freedman, 1974).

TABLE 2. PRINCIPAL WATER QUALITY AND BIOLOGICAL SURVEYS OF SAGINAW BAY

AGENCY	NUMBER OF STATIONS	SURVEY TYPE	SURVEY PERIOD	REFERENCES
Michigan Stream Cont. Commission		Water Quality	Summer, 1935-36	MSCC (1937)
Great Lakes Fish. Commission	50	Water Quality	June-Oct, 1956	Beeton, et al. (1967)
Fed. Water Poll. Cont. Adm.	33	Water Quality, Biology	July-Oct. 1965	U.S. FWPCA (1969)
U.S. Lake Survey Center	4	Water Quality	1966	U.S. Lake Survey (1966)
Great Lakes Res. Div., Univ. of Michigan	6	Water Quality	July, 1970	Schelske and Roth (1973)
Beak Consultants		Biology	1970-71	Beak Consultants (1971, 1972)
Dow Chem. Co.	29	Water Quality, Biology	Aug.-Sept. 1971	Batchelder (1973)

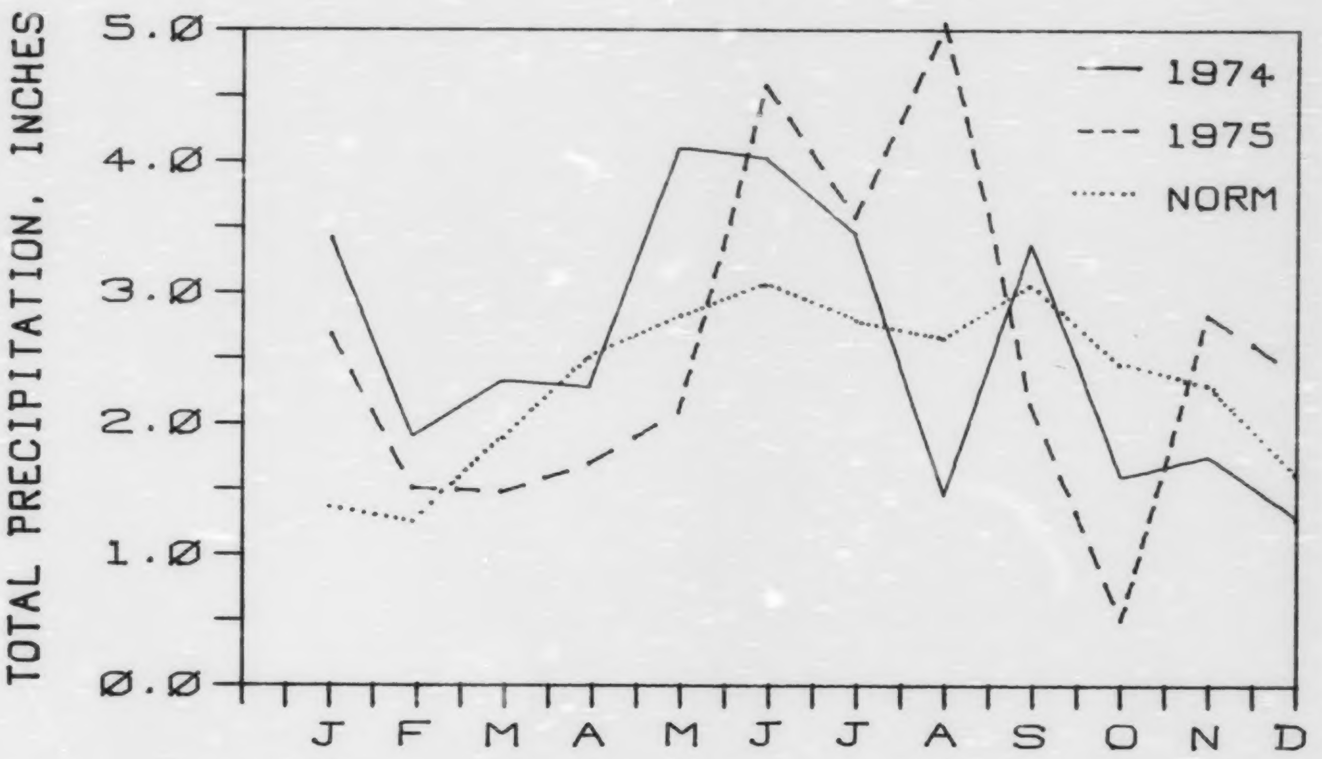


Figure 9. Average monthly precipitation near Saginaw Bay, 1974 and 1975. (Standish, Bay City and Sebewaing stations, U.S. Dept. of Commerce Climatological Data).

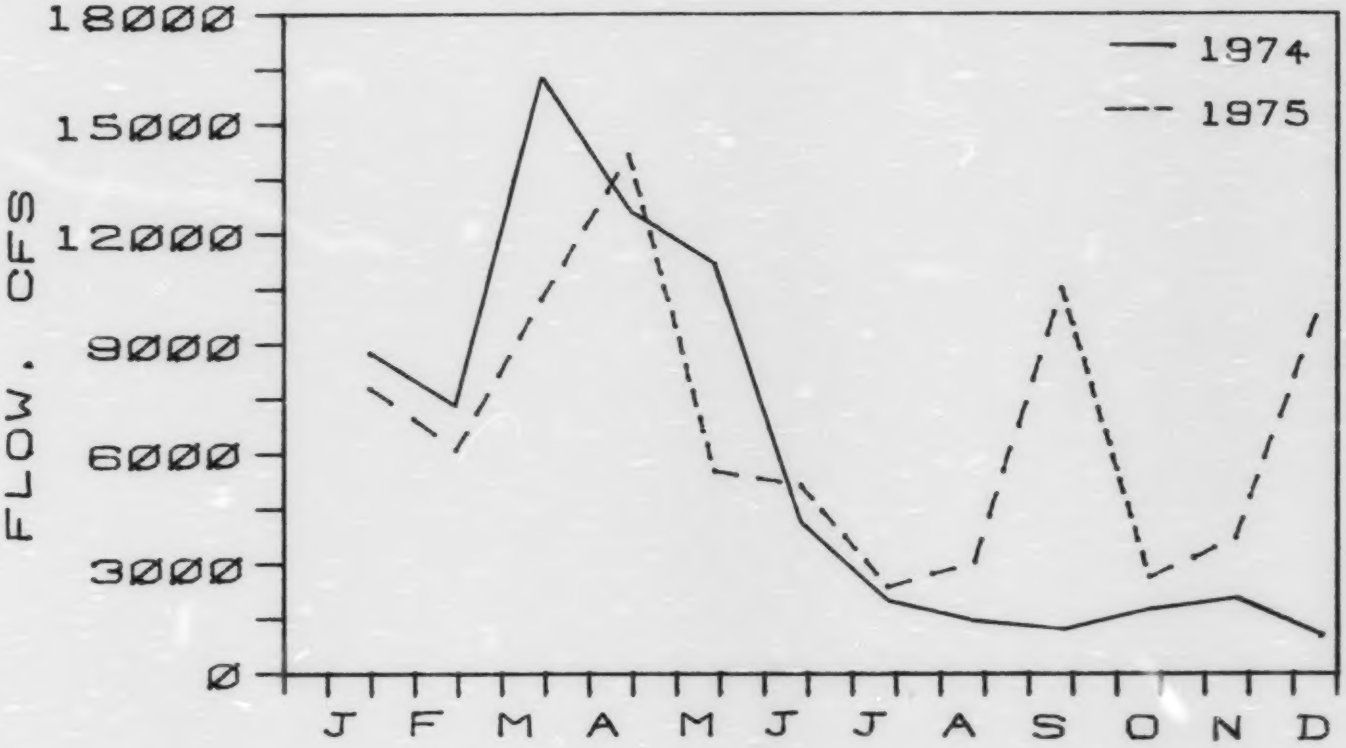


Figure 10. Average monthly flows in lower Saginaw River (Bay City), 1974-75 (U.S. Geological Survey data).

SECTION 5

OBJECTIVES

Three major objectives were addressed in this study:

- To establish a baseline of water quality for Saginaw Bay, describing seasonal and spatial changes in bay parameters over a two-year period.
- To provide data for modeling of hydrological processes and plankton growth dynamics in the bay.
- To prepare a comprehensive water quality document on Saginaw Bay for the International Joint Commission (Upper Lakes Reference Group).

Minor objectives during the study included coordination of this work with that of other agencies mentioned in the introduction.

SECTION 6

METHODS

DATA ACQUISITION

General Approach

In 1974-1975 a total of 30 (plus 2 prior) survey cruises were conducted on Saginaw Bay and in the lower Saginaw River. Most of the field work was done by Institute personnel assisted at times by the U.S. Coast Guard, Air Rescue Station at Selfridge Air National Guard Base, and by other grantees from the University of Michigan, Great Lakes Research Division and Biological Station. Ship support and operators were furnished in 1974 by the National Oceanic and Atmospheric Administration, Lake Survey Center, and in 1975 by the Environmental Protection Agency, Large Lakes Research Station (EPA/LLRS) at Grosse Ile.

During the April - October period most cruises were scheduled every 18 days to coincide with coverage by Landsat, formerly the Earth Resources Technology Satellite (ERTS-1 and ERTS-2). During the winter a partial survey by helicopter or ground team took place approximately once a month. Six diurnal surveys at a single station were also completed in 1975. The cruise and satellite dates, as well as the station coverage, are shown in Table 3.

Generally, field measurements and samples for laboratory analyses were taken at selected stations and depth intervals throughout Saginaw Bay and in the lower Saginaw River. In 1974 the cruises covered a maximum of 59 stations and 111 depth-levels; in 1975 a subset of 37 stations (including two new ones) and 73 depth-levels were sampled. Only 1 meter samples were collected by helicopter. The station coordinates and levels sampled are given in Table 4. The location of all stations is shown on the map in Figure 11, which also indicates a subdivision of the bay into 5 segments or sub-areas. These were established by EPA modelers to provide spatial resolution within the bay. The presumed homogeneity of segments was based on 1974 water quality data and on the results of a current meter study (Richardson amd Bierman, 1976). The segments are used in this report primarily for data summation purposes.

Typically, each survey-cruise was conducted over a 3-day period by two boats: one was a 45-60 ft. vessel, usually equipped with some laboratory facilities; the other was an 18-22 ft. outboard craft with only portable monitoring equipment and sampling gear. In usual practice the small boat

TABLE 3. SCHEDULE OF CRUISES AND DIURNAL SURVEYS

CRUISE/SURVEY	SAMPLING DATES	NO. STATIONS SAMPLED	SATELLITE PASS DATES
Cruise 1	11/5-7/73	37	10/31-11/1/73
Cruise 2	12/3-4/73	41	12/5 & 6/73
Cruise 3	2/18-21/74	16	2/15 & 16/74
Cruise 4	3/25/74	7	3/23 & 24/74
Cruise 5	4/16-20/74	44	4/10 & 11/74
Cruise 6	4/28-30/74	59	4/28 & 29/74
Cruise 7	5/13-17/74	51	5/16 & 17/74
Cruise 8	6/2-5/74	47	6/3 & 4/74
Cruise 9	6/18-22/74	59	6/21 & 22/74
Cruise 10	7/8-10/74	59	7/9 & 10/74
Cruise 11	7/25-27/74	59	7/27 & 28/74
Cruise 12	8/25-27/74	59	9/1 & 2/74
Cruise 13	9/18-20/74	59	9/19 & 20/74
Cruise 14	10/6-8/74	58	10/7 & 8/74
Cruise 15	11/11-14/74	36	11/12 & 13/74
Cruise 16	12/16-18/74	23	12/18 & 19/74
Cruise 17	2/17-19/75	33	2/20 & 21/75
Cruise 18	3/18/75	15	3/27 & 28/75
Cruise 19	4/9-11/75	30	4/1 & 2/75
Diurnal Survey (Sta. 56)	4/28-29/75	1	
Cruise 20	4/30-2/75	37	5/1 & 2/75
Cruise 21	5/20-22/75	37	5/19 & 20/75
Diurnal Survey (Sta. 56)	6/2-3/75	1	
Cruise 22	6/5-8/75	32	6/6 & 7/75
Cruise 23	6/25-27/75	37	6/24 & 25/75
Diurnal Survey (Sta. 56)	7/11-12/75	1	
Cruise 24	7/13-16/75	37	7/12-13/75
Cruise 25	7/29-31/75	36	7/30-31/75
Diurnal Survey (Sta. 56)	8/16-17/75	1	
Cruise 26	8/18-20/75	37	8/17 & 18/75
Cruise 27	9/3-5/75	37	9/4 & 5/75
Diurnal Survey (Sta. 56)	9/21/75	1	
Cruise 28	9/23/75	19	9/22 & 23/75
Cruise 29	10/9-11/75	37	10/10 & 11/75
Diurnal Survey (Sta. 56)	10/25-26/75	1	
Cruise 30	10/27-29/75	29	10/28 & 29/75
Cruise 31	11/16-18/75	35	11/15 & 16/75
Cruise 32	12/16/75	9	12/21 & 22/75

TABLE 4. STATIONS AND DEPTHS SAMPLED

Station	Coordinates		Depths				
	N. Latitude	W. Longitude	1m	5m	10m	15m	Bot.-1m
1	43° 38' 10"	83 51' 00"	X				X
2	43° 43' 05"	83 54' 05"	X				
3	43° 51' 25"	83 54' 15"	X				
4	44° 06' 30"	83 31' 45"	X	X	X		
5	43° 40' 50"	83 52' 20"	X				
* 6	43° 40' 20"	83 50' 00"	X	X			X
7	43° 41' 05"	83 50' 35"	X				
8	43° 40' 00"	83 48' 25"	X				X
* 9	43° 39' 20"	83 50' 55"	X				X
*10	43° 41' 20"	83 49' 10"	X				X
*11	43° 40' 00"	83 44' 15"	X				X
12	43° 38' 25"	83 39' 40"	X				X
*13	43° 41' 05"	83 46' 45"	X	X			
*14	43° 42' 50"	83 49' 15"	X	X			
*15	43° 44' 50"	83 51' 40"	X	X			
*16	43° 46' 55"	83 54' 45"	X				X
*17	43° 42' 10"	83 44' 10"	X	X			
18	43° 44' 30"	83 46' 25"	X	X			
*19	43° 46' 55"	83 48' 50"	X	X			
*20	43° 49' 50"	83 52' 00"	X				
*21	43° 40' 15"	83 52' 50"	X				
22	43° 49' 25"	83 48' 40"	X	X			
*23	43° 48' 35"	83 44' 40"	X	X			
*24	43° 47' 00"	83 39' 20"	X	X			
*25	43° 41' 40"	83 35' 50"	X				
26	43° 45' 40"	83 31' 35"	X				X
27	43° 49' 10"	83 37' 10"	X	X			
*28	43° 51' 35"	83 40' 25"	X	X			
29	43° 54' 50"	83 44' 50"	X	X			
30	43° 58' 05"	83 49' 15"	X				
*31	43° 56' 10"	83 40' 40"	X	X			
32	43° 54' 35"	83 31' 40"	X				
*33	43° 50' 20"	83 30' 15"	X				
34	43° 53' 00"	83 23' 35"	X				
35	43° 58' 45"	83 34' 40"	X	X	X		
36	44° 01' 20"	83 39' 45"	X				
37	44° 01' 05"	83 32' 30"	X	X			
38	43° 58' 10"	83 24' 55"	X				
*39	44° 55' 40"	83 19' 50"	X				
*40	43° 04' 35"	83 34' 25"	X				
41	43° 38' 55"	83 50' 55"	X				
42	44° 03' 45"	83 25' 50"	X	X			
43	44° 01' 25"	83 20' 25"	X	X			
44	43° 59' 00"	83 16' 20"	X	X			
45	44° 11' 15"	83 33' 00"	X				
*46	44° 00' 25"	83 08' 40"	X				
47	44° 16' 30"	83 29' 25"	X				
48	44° 14' 20"	83 28' 20"	X	X			
49	44° 12' 40"	83 22' 40"	X	X	X	X	X
50	44° 10' 20"	83 17' 30"	X	X	X	X	X
51	44° 07' 25"	83 10' 15"	X	X	X	X	X
52	44° 04' 10"	83 04' 50"	X	X	X	X	X
53	44° 03' 20"	83 00' 15"	X	X			
54	43° 36' 45"	83 51' 25"	X				
55	43° 36' 20"	83 53' 25"	X				
56	43° 43' 45"	83 37' 40"	X				
*57	44° 08' 05"	83 23' 45"	X	X	X		
*58	44° 03' 15"	83 12' 45"	X	X	X		
*59	43° 40' 50"	83 53' 45"	X				X
**60	43° 58' 55"	83 30' 00"	X				
**61	43° 55' 40"	83 26' 25"	X				

(* 1974 Only)
(** 1975 Only)

Segment	Station Numbers	No. Stations
1	2,5,6,7,8,10,11,12,13,14,15,16,21,59	14
2	3,17,18,19,20,22,23,24,27,28,29,30 3k,32,35,36,60	17
3	25,26,33,34,55,61	6
4	4,37,40,42,45,47,48,49,50,57	10
5	38,39,43,44,46,51,52,53,58	9
River	1,9,41,54,55	5
	TOTAL	61

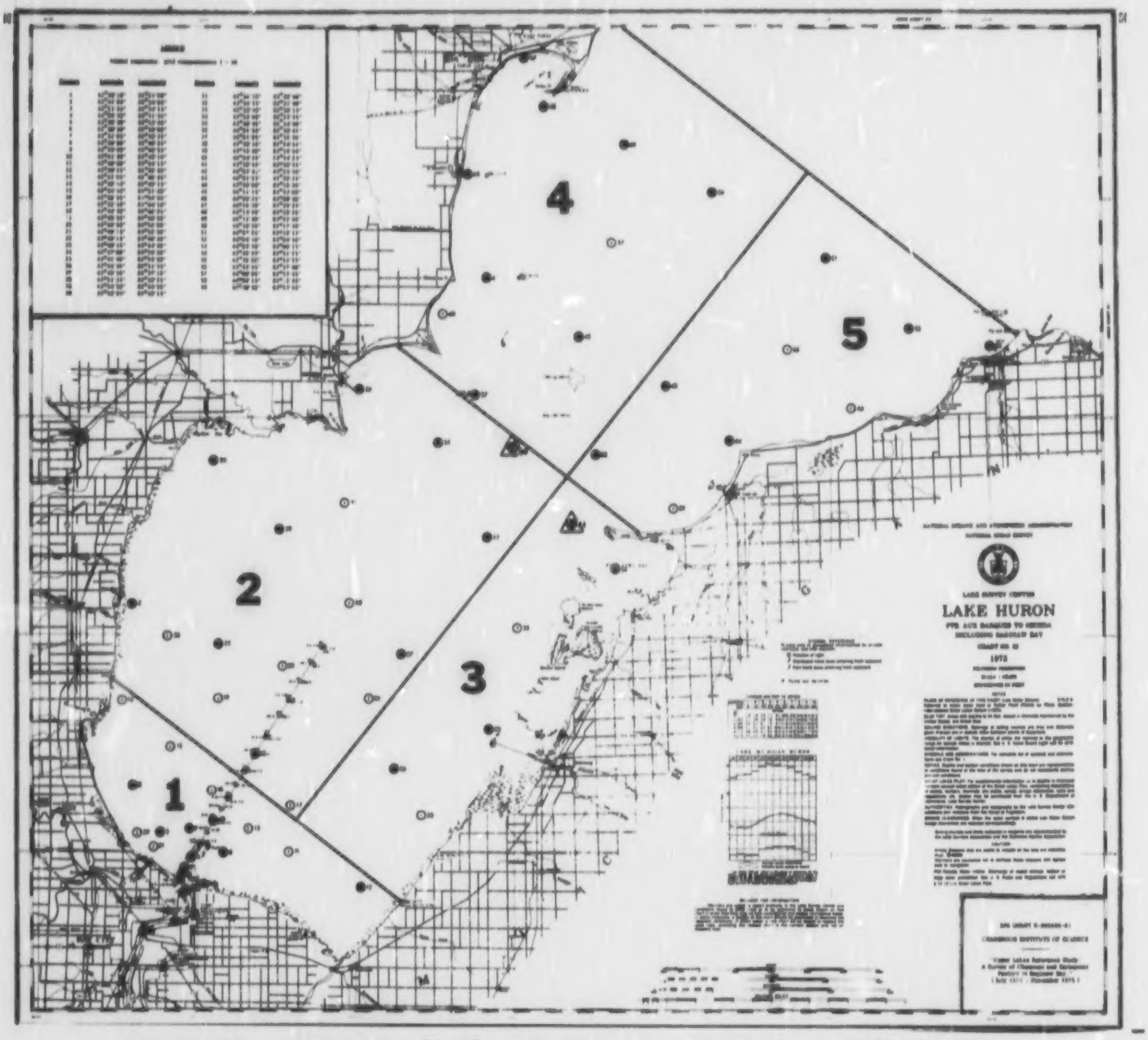


Figure 11. Segments (1-5) and stations sampled in 1974 (1-59) and 1975 (37 indicated by ⊙ and △).

worked the inshore stations, delivering samples to the laboratory vessel every few hours for processing. The tracks covered by both vessels on a representative cruise are shown in Figure 12. Stations were located by using a combination of timed runs from reference points, known depths and compass bearings from shore features in some cases. Positioning for the larger vessels and helicopters was assisted by radar and radio beacons, respectively. Station-finding accuracy was considered to be generally within a quarter mile.

Field Sampling

Water samples were collected using an all-plastic Kemmerer (4 liter) or Niskin (5 liter) sampler, or by rubber hose and oil-free centrifugal pump. All bottles used were of Nalgene (polypropylene), machine washed without detergents, rinsed with 10% HCl (nutrients) or 2% HNO_3 (metals), rinsed with distilled water (Millipore Super-Q) and dried at 95°C. The small boat samples were kept temporarily in insulated chests (in darkness) at ambient water temperatures; after receipt by the lab vessel they were refrigerated. For filtered nutrient analysis, water was (in 1974) passed through 0.45 μm Millipore type HA filters; later (1975), Whatman GF/F glass fiber filters were used instead to reduce contamination (Filkins and Mullin, 1976). All nonfilterable chlorophyll samples were collected on Whatman GF/C filters. All samples were transported on ice within 30 hours to EPA/LLRS where nutrient analyses were generally completed within a further 24 hours. For some other parameters samples were refrigerated or frozen longer (see Table 5). Filters containing chlorophylls and all intake plant water samples were kept frozen until analysis. The intake samples were analyzed for chloride, chlorophyll *a*, total phosphorus and total Kjeldahl nitrogen only.

Field and Laboratory Analyses

Table 5 summarizes the methodology used for each parameter. Complete descriptions of the methods and procedures, as modified in some cases (Table 5), are on file at EPA/LLRS, Grosse Ile.

Quality Control

Quality control for automated nutrient and metals analyses involved using replicate standards and samples, dilution of standards and samples, addition of standards to samples, laboratory intercomparisons of samples and analysis of EPA test standards. Two or more replicate samples for chlorophylls were run on some cruises. All carbon analyses were done in triplicate. Any extreme value in each triplicate (i.e., 20% different from the other two) was rejected, and the remaining two were averaged. Total solids samples including some replicates were analyzed by a commercial laboratory. Details of the quality control procedures are on file at EPA/LLRS, Grosse Ile.

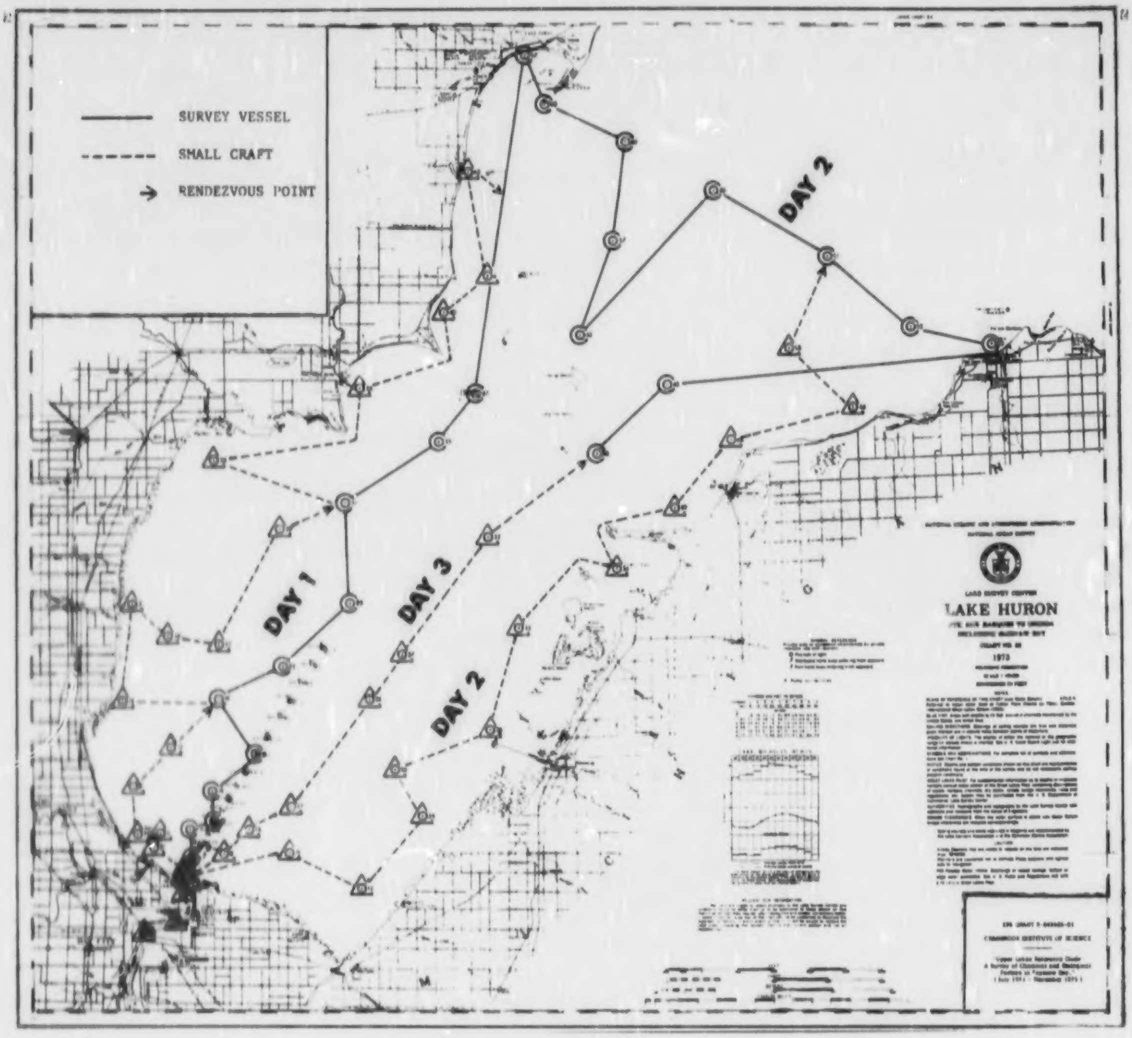

SURVEY VESSEL
SMALL CRAFT
RENDEZVOUS POINT
DAY 1
DAY 2
DAY 3
DAY 2
LAKE HURON
1973

Figure 12. Typical cruise tracks followed in 1974 (Cruise 9, June 18-27).

TABLE 5. METHODS AND EQUIPMENT

PARAMETER	WHERE MEASURED -			MAX. TIME TO ANALYSIS	METHODS	EQUIPMENT/ INSTRUMENTATION	SOURCE OF METHOD
	IN SITU	ON SHIP	AT LLRS				
Temperature	X	X		(in situ)	Submerged thermistor probe; thermometry	Martek Mark II Monitor	Martek Manual (1973)
Oxygen, dissolved	X			(in situ)	Submerged KCl probe	Martek Mark II Monitor	Martek Manual (1973)
Specific Conductivity		X		10 min.	Electric conductance measurement	Beckman RC19 Conductivity Bridge	Beckman Manual (1973)
Chloride, filtered			X	48 hrs.	Ferric thiocyanate color reaction	Technicon AA2 Auto analyzer	Technicon Industrial Method No. 99-70W (1973)
pH	X	X		10 min.	Submerged combination pH probe	Martek Mark II Monitor Fisher 520 pH/Ion Meter	Martek Manual (1973)
Akalinity, total		X		10 min.	Sulfuric acid (0.02N) titration to pH 4.5	Burette & Fisher 520 pH/Ion Meter	Standard Methods, 13th Ed., (1971)
Secchi disc depth	X			(in situ)	Visual estimation	9 cm diam. B & W disc	Welch (1948)
Chlorophyll a, non-filterable			X	4 wks.	Extraction & spectrophotometry (SCOR/UNESCO)	P-E Coleman 124 Double Beam Spectrophotometer	Strickland and Parsons (1968)
Carbon, filt. organic			X	2 wks-sealed 7 mos-analyzed	Sealed ampuole wet oxidation & IR analysis	Oceanography International 052413 & MSA 300 IR analyzer	O.I. Proceedures Modified (1974)
Carbon, unfilt. organic			X	2 wks-sealed 7 mos-analyzed	Sealed ampuole wet oxidation & IR analysis	Oceanography International 052413 & MSA 300 IR analyzer	O.I. Proceedures Modified (1974)
Solids, unfilt. total			X	2 wks.	Gravimetric measurement	Mettler H10 Balance	Standard Methods, 13th Ed., (1971)
Silicates, filt. reactive			X	48 hrs.	"Molybdenum blue" color reaction	Technicon AA2 Auto analyzer	Technicon Industrial Method No. 105-71W (1973)
Ammonia, filtered total			X	48 hrs.	Berthelot color reaction	Technicon AA2 Auto analyzer	Technicon Industrial Method No. 154-71W (1973)
Nitrate + Nitrite, filt.			X	48 hrs.	Sulfanilimide (diazo) color reaction	Technicon AA2 Auto analyzer	Technicon Industrial Method No. 100-70W (1973)
Nitrogen, unfilt. Kjeldahl			X	48 hrs.	Digestion & autoanalysis for ammonia	Heating Block and Technicon AA2 Auto analyzer	LLRS modification of EPA Corvallis method (1974)
Phosphates, filt. reactive			X	48 hrs.	"Phospho-molybdenum blue" color reaction	Technicon AA2 Auto analyzer	Technicon Industrial Method No. 155-71W (1973)
Phosphorus, filt. total			X	48 hrs.	Digestion & autoanalysis for phosphate	Heating Block & Technicon AA2 Auto analyzer	LLRS modification of EPA Corvallis method (1974)
Phosphorus, unfilt. total			X	48 hrs.	Digestion & autoanalysis for phosphate	Heating Block & Technicon AA2 Auto analyzer	LLRS modification of EPA Corvallis method (1974)
Sodium, unfiltered			X	6 mos.	Flame Atomic Absorption Spectrophotometry (undigested)	Instrumentation Laboratory 353 AA Spectrophotometry	LLRS modification of EPA Corvallis method (1974)
Potassium, unfiltered			X	6 mos.	Flame Atomic Absorption Spectrophotometry (undigested)	Instrumentation Laboratory 353 AA Spectrophotometry	LLRS modification of EPA Corvallis method (1974)
Calcium, unfiltered			X	6 mos.	Flame Atomic Absorption Spectrophotometry (undigested)	Instrumentation Laboratory 353 AA Spectrophotometry	LLRS modification of EPA Corvallis method (1974)
Magnesium, unfiltered			X	6 mos.	Flame Atomic Absorption Spectrophotometry (undigested)	Instrumentation Laboratory 353 AA Spectrophotometry	LLRS modification of EPA Corvallis method (1974)

Data Management and Processing

The management approach involved compiling all field and laboratory data, editing and filing it in the EPA STORET system. Processing included retrieving and plotting the data in various spatial and temporal formats and subjecting data to statistical analysis. These steps are outlined in Figure 13. For all parameters, field and laboratory data sheets were made compatible with STORET punch card formats to streamline the transcription process.

Technicon nutrient Auto-Analyzers were interfaced with a PDP-8E minicomputer (Digital Equipment Corp., DEC) to monitor analyses of up to eight parameters simultaneously. Analog data from the colorimeters were recorded on chart paper and digitized for peak analysis using a modified version of the DEC "PAMILA" program (Peak Analysis for Multi-Instrument Lab Automation).

PAMILA performs digital filtering, peak detection, integration, and baseline determination, and also generates punched paper tape. At the completion of a run, the paper tape is read into core memory, a permanent data file is created on a magnetic disk, and a separate FORTRAN analysis program operates on this data file. This FORTRAN program calculates a standard least-squares calibration curve and converts the peaks to actual chemical concentrations.

The SPSS program (Statistical Package for the Social Sciences), available from Optimum Systems, Inc., was used for both correlation and multiple regression analyses of the retrieved data.

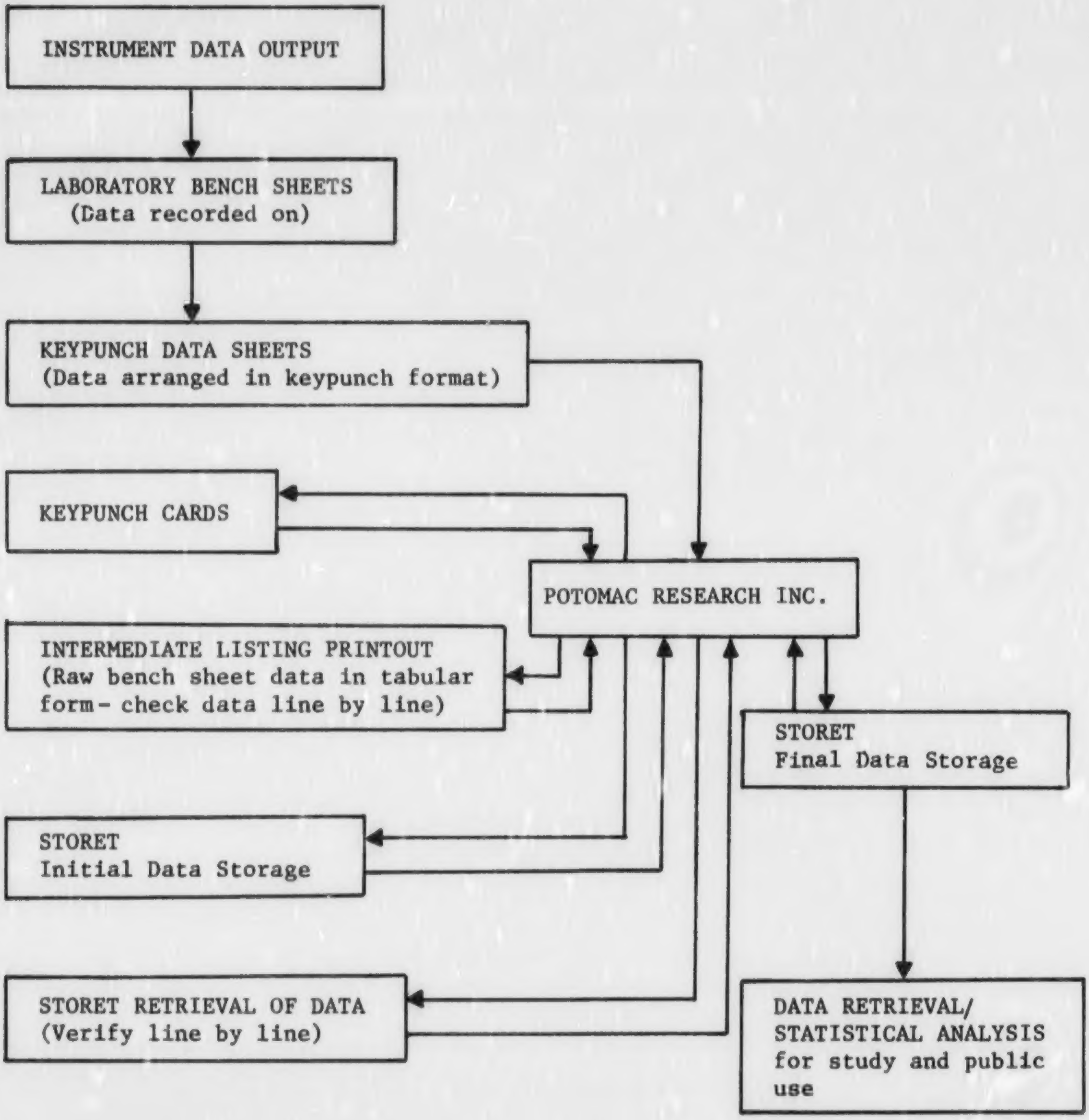

INSTRUMENT DATA OUTPUT
LABORATORY BENCH SHEETS (Data recorded on)
KEYPUNCH DATA SHEETS (Data arranged in keypunch format)
KEYPUNCH CARDS
POTOMAC RESEARCH INC.
INTERMEDIATE LISTING PRINTOUT (Raw bench sheet data in tabular form- check data line by line)
STORET Final Data Storage
STORET Initial Data Storage
STORET RETRIEVAL OF DATA (Verify line by line)
DATA RETRIEVAL/ STATISTICAL ANALYSIS for study and public use

Figure 13. Flow diagram for data management.

SECTION 7

RESULTS

PARAMETER SUMMARIES

The following section summarizes, in tabular and graphical form, the cumulative data for each parameter. An additional brief description highlights some aspects of the data that are not readily apparent from the tables and figures. It is important to note that, for a given spatial or time interval, data from all station-depths were combined and statistically treated as a single data set. In other words, quarterly and annual means were determined directly from individual measurements and not from sets of cruise data for the respective time periods.

Temperature

The highest mean temperature level of 17.9 °C during 1974-75 was recorded at station 34 (segment 3). The lowest of 10.6 °C was at station 49 (segment 4). The 1974-75 mean value of 14.2 °C at station 59 was closest to the total bay mean of 14.1 °C.

Mean values by segment ranged from 11.6 °C (segment 4, 1974) to 16.9 °C (segment 1, 1975). The greatest annual range, 0.3 °C - 29.0 °C, occurred in segment 5, 1974). In 1974 the mean value of 13.3 °C in segment 5 was closest to the total bay mean of 13.6 °C. In 1975 the mean of 14.9 °C in segment 2 was closest to the bay mean of 14.1 °C.

Results showing the variation by cruise (at two depths) of temperature at selected stations are given in Table 6 and Figure 14. Quarterly and annual summaries of all temperature data compiled for each segment and the total bay are shown in Table 7 and Figure 15.

Oxygen, dissolved (d. O_2)

The highest mean dissolved oxygen level of 11.9 mg O_2/ℓ during 1974-75 was recorded at station 50 (segment 4). The lowest of 6.7 mg O_2/ℓ was at station 55 (river). The 1974-75 mean value of 10.2 mg O_2/ℓ at station 18 was identical to the total bay mean.

Mean values by segment ranged from 9.4 mg O_2/ℓ (segment 3, 1975) to 11.6 mg O_2/ℓ (segment 4, 1974). The greatest annual range, 3.0 mg O_2/ℓ - 13.8 mg O_2/ℓ, occurred in segment 3 (1975). In 1974 the mean value of 11.0 mg O_2/ℓ in segment 4 was closest to the total bay mean of 10.6 mg O_2/ℓ. In 1975 the

TABLE 6. TEMPERATURE (^{o}C) AT SELECTED STATIONS PLOTTED IN FIGURE 14

Station Number	Location	Depth In Meters	Mean*	(Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	17.5	(4.5-25.8)	6.4	75-4-11	74-7-8
		8	17.3	(4.5-25.6)	6.5	75-4-11	75-7-29
8	Segment I	1	16.3	(0.5-26.7)	6.9	74-12-17	75-7-31
		3	16.3	(0.5-24.0)	6.5	74-12-17	74-7-10
35	Segment II	1	14.6	(1.5-23.2)	6.4	75-4-9	75-7-13
		10	11.8	(1.0-21.0)	5.2	75-4-9	74-8-15
34	Segment III	1	17.0	(2.2-26.9)	6.6	75-4-10	75-7-31
		3	19.4	(11.1-26.0)	4.5	75-5-2	74-7-9
49	Segment IV	1	13.0	(1.0-21.1)	6.4	75-4-10	75-8-19
		20	7.7	(1.0-15.0)	4.0	75-4-10	75-8-19
51	Segment V	1	13.2	(1.2-21.4)	6.4	75-4-10	75-8-19
		28	6.3	(1.2-10.8)	2.5	75-4-10	75-9-4

*Mid-winter data included for 1 m depth only.

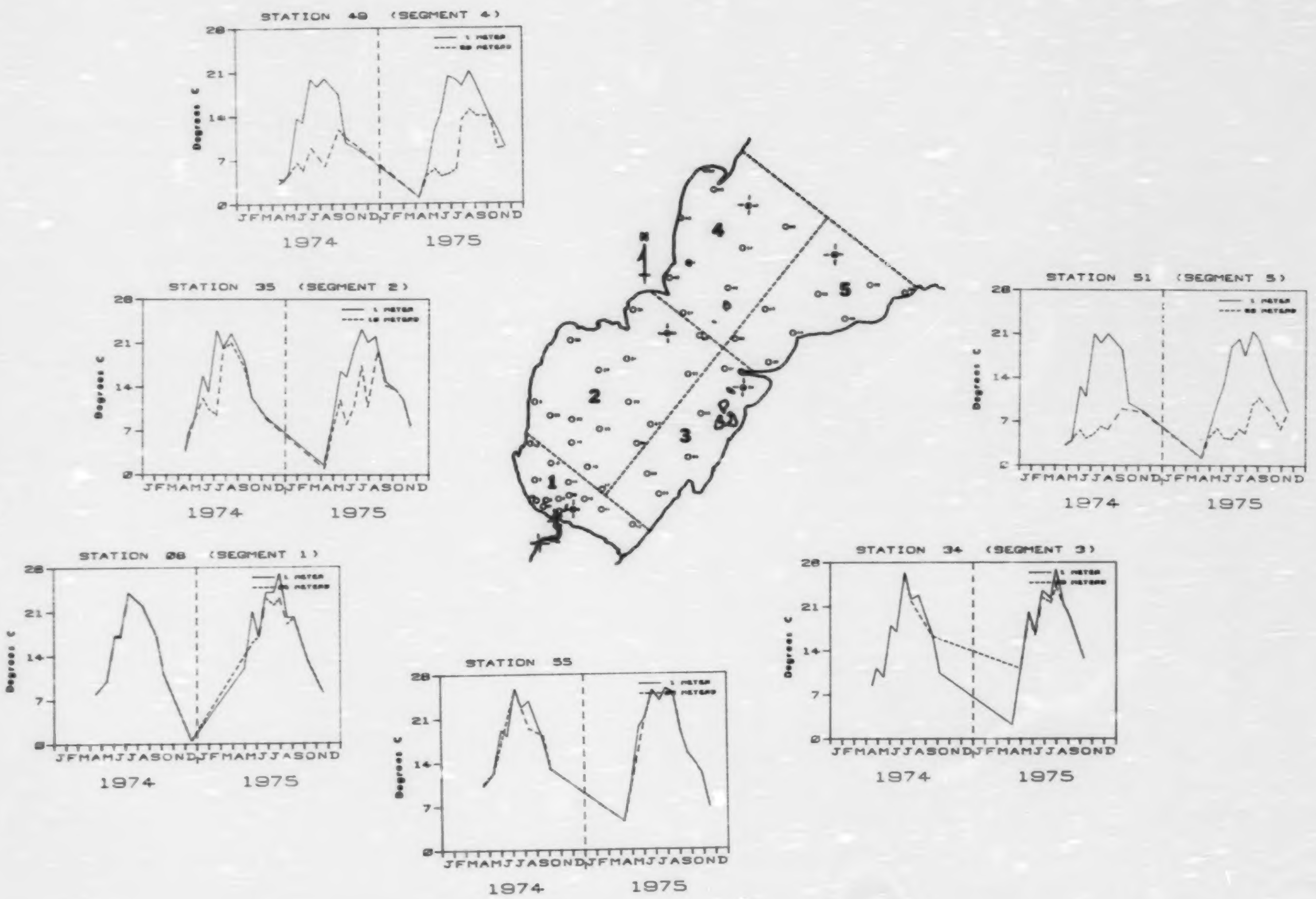


Figure 14. Temperature (°C) at selected stations (-+-).

TABLE 7. DATA SUMMARY OF TEMPERATURE (^{o}C), PLOTTED IN FIGURE 15

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	14.75±5.75	2.0	12.31 ± 4.15	20.72 ± 2.59	9.57 ± 3.32
Range	.3 - 24.0	2.0	5.0 - 18.7	16.0 - 24.0	.3 - 12.6
# of Samples	202	1	96	71	34
Segment II					
Mean ± s.d.	14.5 ± 5.9	-	10.9 ± 4.3	20.2 ± 2.7	10.1 ± 3.2
Range	.1 - 26.4	-	3.8 - 18.7	9.5 - 26.4	.1 - 13.0
# of Samples	277	-	125	111	41
Segment III					
Mean ± s.d.	14.7 ± 6.9	1.0 ± 0	12.5 ± 3.8	21.4 ± 3.3	7.8 ± 4.0
Range	.2 - 26.4	1.0	6.0 - 18.0	16.2 - 26.4	.2 - 10.7
# of Samples	68	3	29	26	10
Segment IV					
Mean ± s.d.	11.6 ± 5.5	-	8.0 ± 4.1	16.8 ± 4.1	9.7 ± 1.5
Range	2.5 - 22.0	-	2.5 - 16.9	5.0 - 22.0	7.0 - 12.5
# of Samples	256	-	116	95	45
Segment V					
Mean ± s.d.	13.3 ± 5.8	-	9.8 ± 4.5	18.2 ± 4.2	9.7 ± 1.2
Range	.3 - 29.0	-	.3 - 18.7	5.0 - 29.0	7.2 - 11.3
# of Samples	200	-	83	83	34
Total Bay					
Mean ± s.d.	13.6 ± 5.9	1.1 ± .5	10.4 ± 4.5	19.1 ± 3.8	9.6 ± 2.6
Range	.1 - 29.0	1.0 - 2.0	.3 - 18.7	5.0 - 29.0	.1 - 13.0
# of Samples	1,003	4	449	386	164

1975

Segment 1					
Mean ± s.d.	16.8 ± 6.7	1.1 ± 1.2	16.9 ± 6.1	21.3 ± 3.0	10.9 ± 2.7
Range	.1 - 26.8	.1 - 2.5	1.5 - 24.6	14.4 - 26.8	7.0 - 13.4
# of Samples	64		23	26	12
Segment II					
Mean ± s.d.	14.9 ± 6.2	1.0	12.7 ± 6.7	19.8 ± 2.9	10.7 ± 2.7
Range	1.0 - 25.0	1.0	1.0 - 23.0	10.8 - 25.0	5.8 - 13.6
# of Samples	199	1	80	75	43
Segment III					
Mean ± s.d.	16.9 ± 7.2	2.1 ± 1.3	14.7 ± 7.3	22.1 ± 2.3	11.8 ± 2.2
Range	1.2 - 26.9	1.2 - 3.0	1.3 - 23.5	19.0 - 26.9	8.0 - 13.0
# of Samples	50	2	23	20	5
Segment IV					
Mean ± s.d.	12.8 ± 6.0	-	9.2 ± 6.0	17.9 ± 4.1	11.1 ± 2.3
Range	1.0 - 21.9	-	1.0 - 20.3	5.5 - 21.9	5.5 - 13.9
# of Samples	230	-	90	83	57
Segment V					
Mean ± s.d.	13.1 ± 6.3	-	9.3 ± 5.3	19.4 ± 4.0	10.5 ± 2.6
Range	1.2 - 25.1	-	1.2 - 19.2	5.1 - 25.1	5.8 - 13.7
# of Samples	182	-	72	64	46
Total Bay					
Mean ± s.d.	14.1 ± 6.5	1.4 ± 1.0	11.3 ± 6.6	19.4 ± 3.8	10.8 ± 2.6
Range	.1 - 26.9	.1 - 3.0	1.0 - 24.6	5.1 - 26.9	5.5 - 13.9
# of Samples	725	6	288	268	163

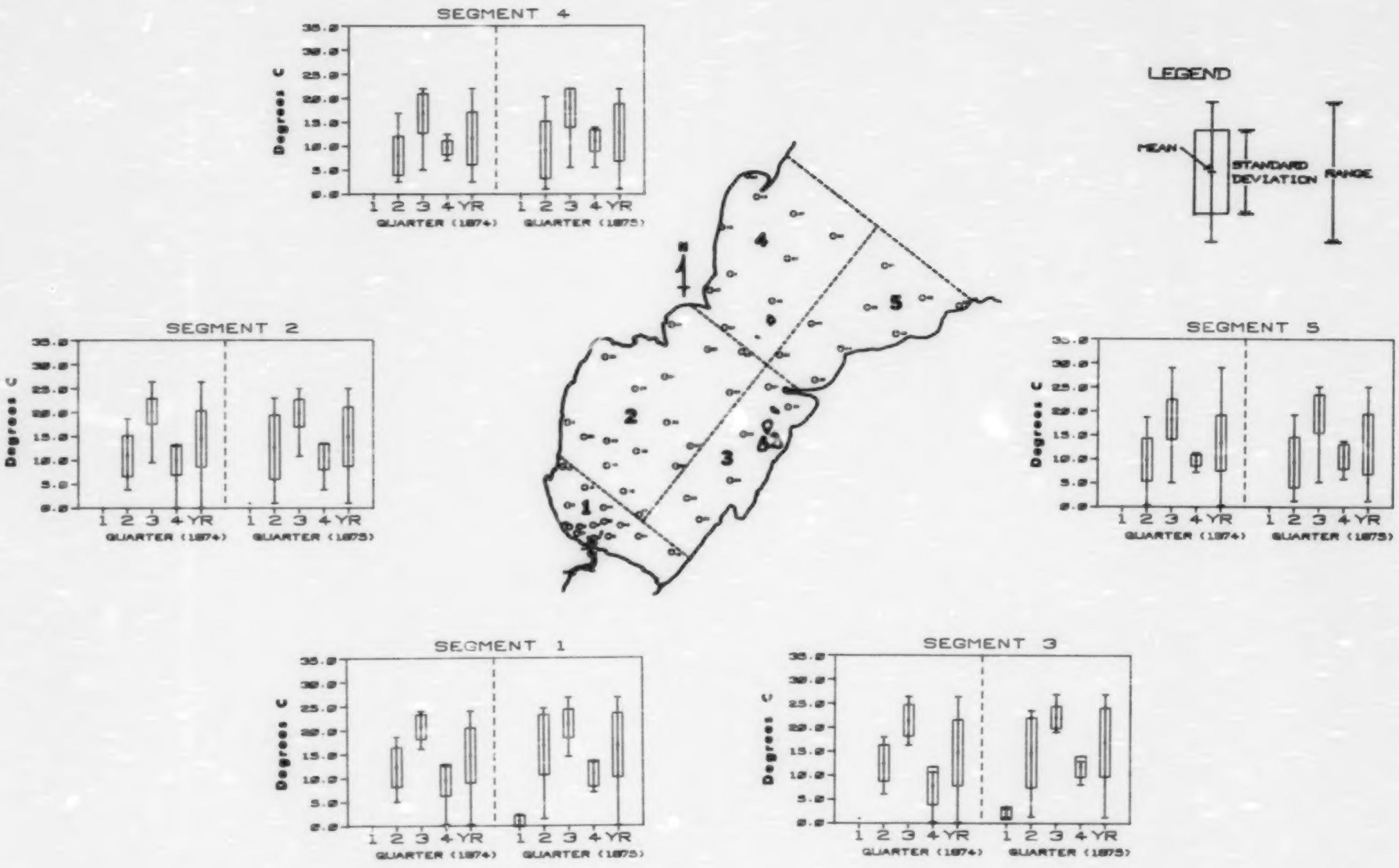


Figure 15. Data summary of temperature (°C).

mean of 10.6 mg O_2/ℓ in segment 4 was identical to the bay mean.

Quarterly and annual summaries of all d. oxygen data compiled for each segment and the total bay are shown in Table 8 and Figure 16.

Conductivity (sp. cond.)

The highest mean specific conductivity level of 702 µS/cm during 1974-75 was recorded at station 55 (river). The lowest of 204 µS/cm was at station 49 (segment 4). The 1974-75 mean value of 295 µS/cm at station 56 was identical to the total bay mean.

Mean values by segment ranged from 211 µS/cm (segment 4, 1974) to 334 µS/cm (segment 1, 1974). The greatest range, 230 µS/cm - 843 µS/cm, occurred in segment 1 (1974). In 1974 the mean value of 265 µS/cm in segment 2 was closest to the total bay mean of 260 µS/cm. In 1975 the mean of 258 µS/cm in segment 2 was closest to the bay mean of 248 µS/cm.

Quarterly and annual summaries of all sp. conductivity data compiled for each segment and the total bay are shown in Table 9 and Figure 17.

Chloride, filtered (f. Cl)

The highest mean filtered chloride level of 83.5 mg Cl/ℓ during 1974-75 was recorded at station 54 (river). The lowest of 5.9 mg Cl/ℓ was at station 50 (segment 4). The 1974-75 mean value of 18.8 mg Cl/ℓ at station 10 was closest to the total bay mean of 18.7 mg Cl/ℓ.

Mean values by segment ranged from 7.0 mg Cl/ℓ (segment 4, 1974) to 23.2 mg Cl/ℓ (segment 1, 1974). The greatest annual range, 5.4 mg Cl/ℓ - 85.4 mg Cl/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 13.4 mg Cl/ℓ in segment 2 was closest to the total bay mean of 13.2 mg Cl/ℓ. In 1975 the mean of 12.2 mg Cl/ℓ in segment 2 was closest to the bay mean of 11.2 mg Cl/ℓ.

Results showing the variation by cruise (at two depths) of f. chloride at selected stations are given in Table 10 and Figure 18. Quarterly and annual summaries of all chloride data compiled for each segment and the total bay are shown in Table 11 and Figure 19.

pH

The highest mean pH level of 9.0 during 1974-75 was recorded at station 33 (segment 3). The lowest of 7.9 was at station 54 (river). The 1974-75 mean value of 8.4 at station 45 was identical to the total bay mean.

Mean values by segment ranged from 8.2 (segment 4, 1974) to 8.8 (segment 3, 1974 and 1975). The greatest annual range, 6.9 - 9.4 occurred in segment 2 (1974). In 1974 the mean value of 8.4 in segment 5 was closest to the bay mean.

TABLE 8. DATA SUMMARY OF DISSOLVED OXYGEN (mg O_2/ℓ), PLOTTED IN FIGURE 16

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	10.1 ± 1.6	16.0	10.4 ± 1.6	9.40 ± 1.4	10.7 ± .6
Range	4.7 - 16.0	16.0	5.2 - 13.9	4.7 - 11.9	9.5 - 11.5
# of Samples	156	1	75	61	19
Segment II					
Mean ± s.d.	10.1 ± 2.0	-	10.9 ± 1.8	9.2 ± 1.8	10.4 ± .3
Range	1.8 - 14.0	-	5.6 - 14.0	1.8 - 13.6	9.9 - 10.7
# of Samples	205	-	107	89	9
Segment III					
Mean ± s.d.	10.1 ± 1.7	14.3 ± .6	9.8 ± 1.4	9.3 ± .9	10.7 ± .5
Range	7.6 - 14.8	13.4 - 14.8	8.0 - 12.6	7.6 - 11.3	10.2 - 11.8
# of Samples	50	4	17	21	8
Segment IV					
Mean ± s.d.	11.6 ± 1.8	-	12.4 ± 1.5	10.3 ± 1.4	10.3 ± .2
Range	8.8 - 15.5	-	8.9 - 14.8	8.8 - 15.5	10.1 - 10.6
# of Samples	175	-	110	61	4
Segment V					
Mean ± s.d.	11.0 ± 1.6	13.0	11.9 ± 1.6	10.1 ± 1.2	10.3 ± .2
Range	8.1 - 15.0	13.0	8.7 - 15.0	8.3 - 13.6	10.0 - 10.5
# of Samples	119	1	56	54	8
Total Bay					
Mean ± s.d.	10.6 ± 1.9	14.3 ± 1.1	11.3 ± 1.8	9.7 ± 1.5	10.5 ± .48
Range	1.8 - 16.0	13.0 - 16.0	5.2 - 15.0	1.8 - 15.5	9.5 - 11.8
# of Samples	705	6	365	286	48

1975

Segment 1					
Mean ± s.d.	9.9 ± 2.0	11.2	10.7 ± 1.7	8.7 ± 1.8	11.1 ± 1.0
Range	5.8 - 14.0	11.2	7.8 - 14.0	5.8 - 13.5	10.0 - 13.2
# of Samples	58	1	20	25	12
Segment II					
Mean ± s.d.	10.5 ± 1.4	-	10.8 ± 1.2	9.5 ± 1.3	11.6 ± .7
Range	6.4 - 14.3	-	8.0 - 14.3	6.4 - 11.9	9.8 - 12.8
# of Samples	140	-	38	61	41
Segment III					
Mean ± s.d.	9.4 ± 2.3	4.4	10.8 ± 1.9	7.9 ± 1.6	9.9 ± 1.3
Range	3.0 - 13.8	4.4	7.8 - 13.8	3.0 - 10.0	8.7 - 12.0
# of Samples	49	1	23	20	5
Segment IV					
Mean ± s.d.	11.0 ± 1.5	-	12.0 ± 1.4	9.9 ± 1.2	11.3 ± .8
Range	7.9 - 14.2	-	9.8 - 14.2	7.9 - 13.6	9.9 - 12.8
# of Samples	181	-	53	71	57
Segment V					
Mean ± s.d.	10.6 ± 1.6	-	11.9 ± 1.3	9.2 ± 1.3	11.0 ± .7
Range	7.1 - 14.0	-	9.6 - 14.0	7.1 - 13.6	9.6 - 12.2
# of Samples	159	-	54	59	46
Total Bay					
Mean ± s.d.	10.6 ± 1.7	7.8 ± 4.6	11.5 ± 1.5	9.4 ± 1.5	11.2 ± .9
Range	3.0 - 14.3	4.4 - 11.2	7.8 - 14.3	3.0 - 13.6	8.7 - 13.2
# of Samples	587	2	188	236	161

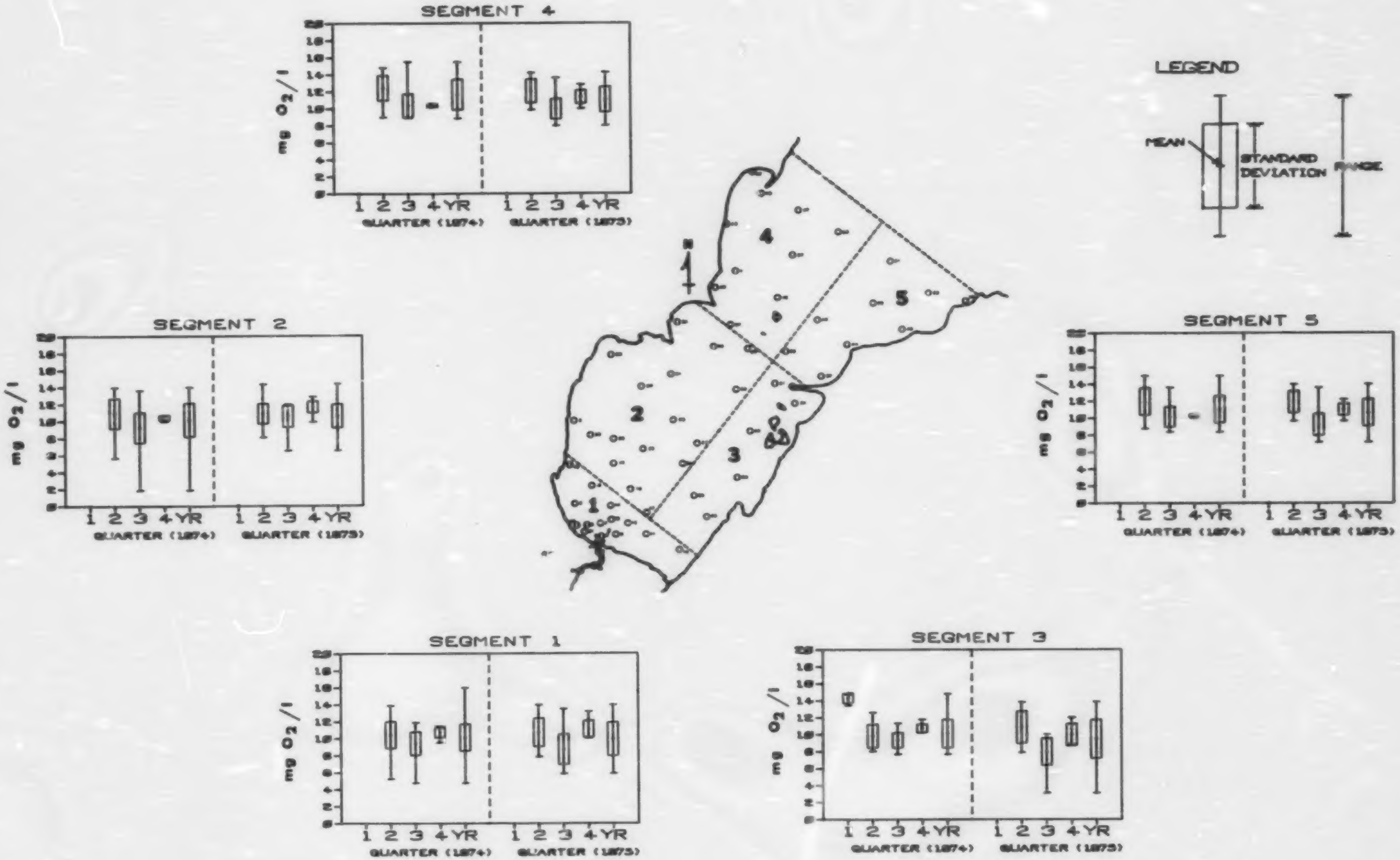


Figure 16. Data summary of dissolved oxygen (mg O_2/ℓ).

TABLE 9. DATA SUMMARY OF SPECIFIC CONDUCTIVITY (μS/cm), PLOTTED IN FIGURE 17

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment I					
Mean ± s.d.	334.5±104.1	413.5 ± 74.3	370.9 ± 112.7	293.3 ± 78.1	316.6 ± 98.1
Range	230 - 843	301 - 490	258 - 828	231 - 843	230 - 609
# of Samples	190	6	81	68	35
Segment II					
Mean ± s.d.	265 ± 38	324 ± 23	293 ± 36	250 ± 22	233 ± 21
Range	130 - 423	307 - 340	222 - 423	130 - 305	164 - 274
# of Samples	260	2	102	111	45
Segment III					
Mean ± s.d.	313 ± 53	364 ± 77	342 ± 56	285 ± 21	284 ± 28
Range	236 - 440	269 - 427	236 - 440	251 - 324	256 - 345
# of Samples	64	5	24	25	10
Segment IV					
Mean ± s.d.	211 ± 24	229 ± 37	216 ± 31	210 ± 14	199 ± 9
Range	102 - 365	201 - 290	102 - 365	188 - 253	178 - 223
# of Samples	260	5	114	95	46
Segment V					
Mean ± s.d.	230 ± 34	223 ± 12	245 ± 41	221 ± 23	214 ± 22
Range	182 - 389	206 - 234	186 - 389	182 - 288	182 - 282
# of Samples	207	4	90	79	34
Total Bay					
Mean ± s.d.	260 ± 72	318 ± 97	280 ± 83	244 ± 49	240 ± 84
Range	102 - 843	201 - 490	102 - 828	130 - 843	164 - 609
# of Samples	981	22	411	378	170

1975

Segment I					
Mean ± s.d.	341 ± 74	377 ± 34	382 ± 75	304 ± 56	315 ± 80
Range	230 - 569	302 - 425	283 - 569	230 - 439	232 - 528
# of Samples	72	10	23	25	14
Segment II					
Mean ± s.d.	250 ± 36	277 ± 45	284 ± 35	237 ± 21	244 ± 24
Range	205 - 400	205 - 400	214 - 400	205 - 307	209 - 311
# of Samples	213	12	79	75	47
Segment III					
Mean ± s.d.	290 ± 43	347 ± 56	296 ± 42	264 ± 22	299 ± 35
Range	222 - 429	275 - 429	222 - 362	225 - 298	252 - 355
# of Samples	56	5	23	20	8
Segment IV					
Mean ± s.d.	215 ± 18	214 ± 10	222 ± 23	212 ± 12	208 ± 15
Range	189 - 282	205 - 233	189 - 222	192 - 262	196 - 273
# of Samples	236	7	90	81	58
Segment V					
Mean ± s.d.	222 ± 22	209 ± 11	222 ± 23	221 ± 16	224 ± 28
Range	184 - 331	194 - 221	184 - 324	197 - 274	200 - 331
# of Samples	186	6	72	62	46
Total Bay					
Mean ± s.d.	248 ± 54	292 ± 75	259 ± 60	236 ± 39	236 ± 47
Range	184 - 569	194 - 429	184 - 569	192 - 439	196 - 528
# of Samples	763	40	287	263	173

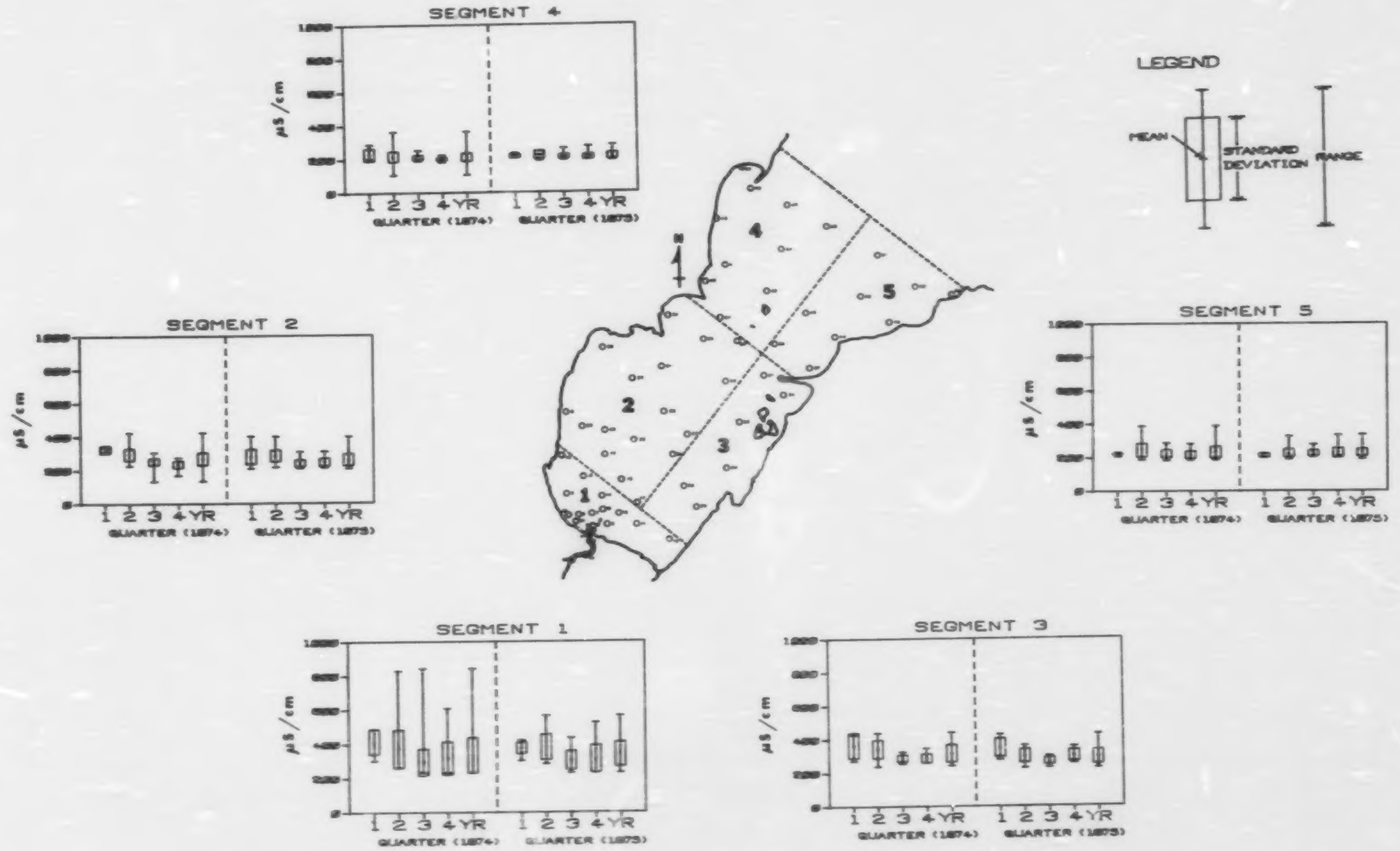


Figure 17. Data summary of specific conductivity (µS/cm).

TABLE 10. FILTERED CHLORIDE (mg Cl/ℓ) AT SELECTED STATIONS, PLOTTED IN FIGURE 18

Station Number	Location	Depth In Meters	Mean *	(Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	81	(25-175)	39	75-9-3	74-10-6
		8	80	(15-180)	40	74-2-21	74-10-6
8	Segment I	1	24	(8-40)	9	75-12-16	74-12-17
		3	22	(8-38)	9	74-12-17	74-12-17
35	Segment II	1	10	(6-15)	3	74-10-6	74-6-3
		10	9	(6-17)	3	74-10-6	75-4-30
34	Segment III	1	19	(10-29)	5	74-2-18	74-5-16
		3	20	(13-30)	4	75-5-22	75-6-27
49	Segment IV	1	8	(5-40)	7	74-4-29	74-2-20
		20	6	(4-6)	1	74-6-19	74-4-20
51	Segment V	1	7	(4-25)	4	74-6-19	74-2-20
		28	6	(3-7)	1	74-7-26	75-4-10

*Mid-winter data included for 1 m depth only.

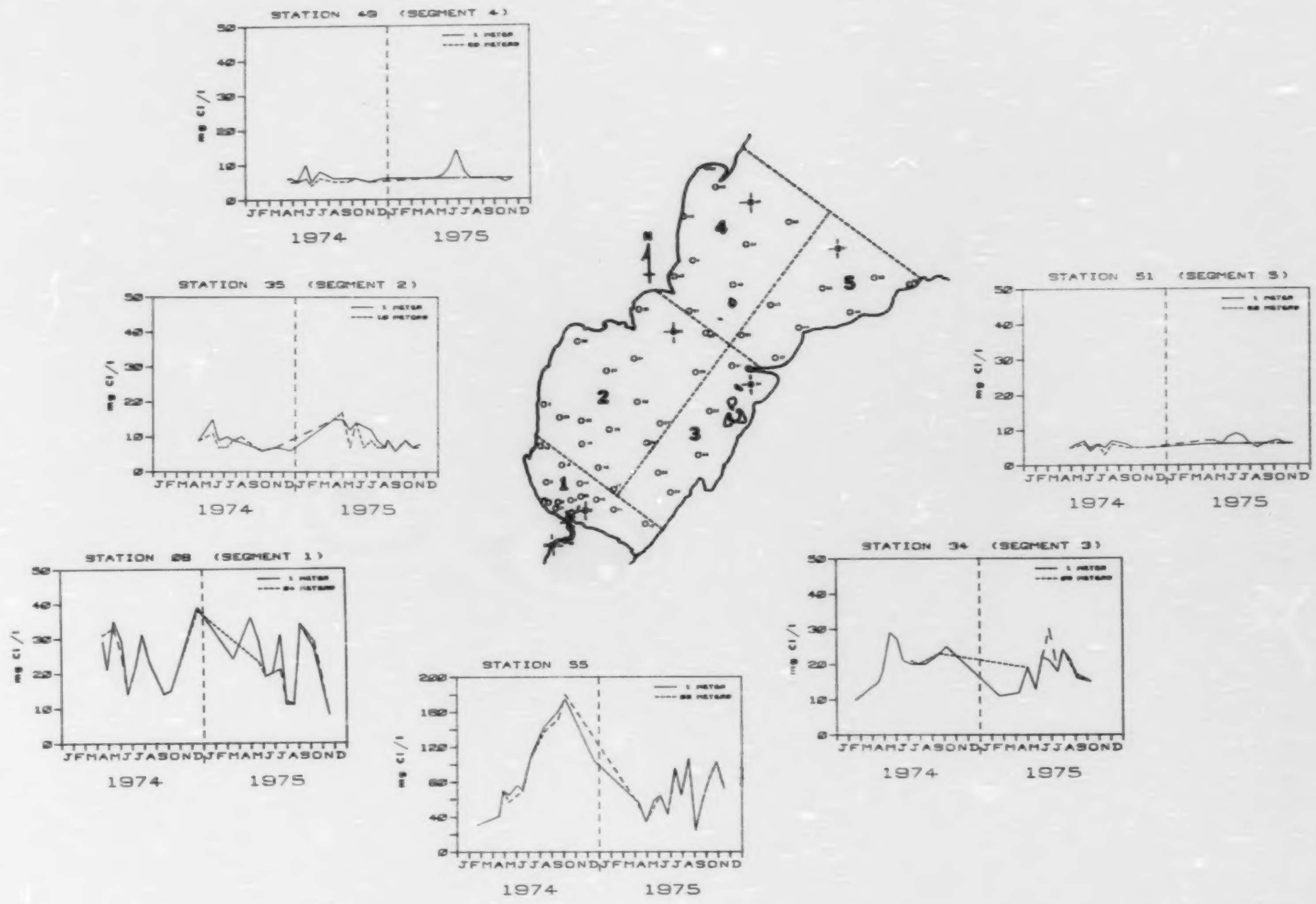


Figure 18. Filtered chloride (mg Cl/ℓ) at selected stations (-+-).

TABLE 11. DATA SUMMARY OF FILTERED CHLORIDE (mg Cl/ℓ), PLOTTED IN FIGURE 19

		Yearly Gross	Quarters			
			1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
1974	**Segment I**					
	Mean ± s.d.	22.9 ± 12.9	13.8 ± 11.9	24.8 ± 11.8	19.4 ± 8.1	26.4 ± 19.7
	Range	5.4 - 85.4	5.4 - 29.3	10.4 - 71.0	10.1 - 43.7	9.7 - 85.4
	# of Samples	201	6	89	70	36
	Segment II					
	Mean ± s.d.	13.4 ± 5.6	21.0 ± 1.1	15.5 ± 4.1	12.5 ± 6.8	10.4 ± 3.1
	Range	2.7 - 67.0	20.2 - 21.8	6.9 - 25.6	2.7 - 67.0	5.9 - 18.5
	# of Samples	260	2	102	109	47
	Segment III					
	Mean ± s.d.	20.0 ± 7.7	8.7 ± 3.1	24.4 ± 8.5	18.8 ± 4.5	17.5 ± 5.7
	Range	6.1 - 40.3	6.1 - 13.5	10.7 - 40.3	10.2 - 26.4	8.7 - 26.0
	# of Samples	68	5	26	26	11
	Segment IV					
	Mean ± s.d.	7.0 ± 4.0	28.6 ± 9.8	6.9 ± 2.9	6.4 ± 1.6	6.0 ± .9
	Range	2.9 - 40.0	14.4 - 40.0	2.9 - 20.5	3.0 - 11.4	4.6 - 9.7
	# of Samples	254	5	110	91	48
	Segment V					
	Mean ± s.d.	9.0 ± 4.4	16.3 ± 6.6	10.1 ± 4.7	7.8 ± 3.8	8.2 ± 3.6
	Range	3.3 - 26.2	9.9 - 25.2	4.4 - 26.2	3.3 - 20.8	4.9 - 21.2
	# of Samples	208	4	85	83	36
	Total Bay					
	Mean ± s.d.	13.2 ± 9.5	17.1 ± 10.6	14.7 ± 9.7	11.7 ± 7.4	12.4 ± 11.9
	Range	2.7 - 85.4	5.4 - 40.0	2.9 - 71.0	2.7 - 67.0	4.6 - 85.4
	# of Samples	991	22	412	379	178
1975	**Segment I**					
	Mean ± s.d.	23.2 ± 8.4	25.5 ± 4.8	27.1 ± 7.3	21.3 ± 8.4	18.6 ± 9.2
	Range	8.3 - 41.8	4.1 - 32.9	15.8 - 41.8	10.5 - 35.4	8.3 - 40.0
	# of Samples	73	10	23	26	14
	Segment II					
	Mean ± s.d.	12.2 ± 4.3	13.3 ± 6.3	15.3 ± 4.2	10.0 ± 2.5	10.3 ± 2.8
	Range	6.2 - 31.9	8.6 - 31.9	7.0 - 24.0	6.2 - 18.3	7.0 - 18.5
	# of Samples	214	12	80	75	47
	Segment III					
	Mean ± s.d.	17.4 ± 5.5	22.7 ± 7.6	17.5 ± 5.9	16.0 ± 3.9	17.2 ± 4.9
	Range	8.2 - 30.5	10.6 - 30.5	8.2 - 30.0	10.4 - 24.1	11.0 - 25.2
	# of Samples	56	5	23	20	8
	Segment IV					
	Mean ± s.d.	7.1 ± 2.3	6.2 ± 1.3	7.9 ± 3.1	6.8 ± 1.3	6.5 ± 1.5
	Range	5.1 - 19.0	5.4 - 8.9	5.3 - 19.0	5.1 - 10.9	5.4 - 13.7
	# of Samples	238	7	90	83	58
	Segment V					
	Mean ± s.d.	8.1 ± 2.8	6.1 ± .6	7.8 ± 2.5	8.5 ± 2.6	8.3 ± 3.5
	Range	5.2 - 21.5	5.5 - 6.9	5.2 - 19.1	5.4 - 18.2	5.5 - 21.5
	# of Samples	188	6	72	64	46
	Total Bay					
	Mean ± s.d.	11.2 ± 6.6	15.4 ± 9.2	12.4 ± 7.2	10.4 ± 5.8	9.7 ± 5.4
	Range	5.1 - 41.8	4.1 - 32.9	5.2 - 41.8	5.1 - 35.4	5.4 - 40.0
	# of Samples	769	40	288	268	173

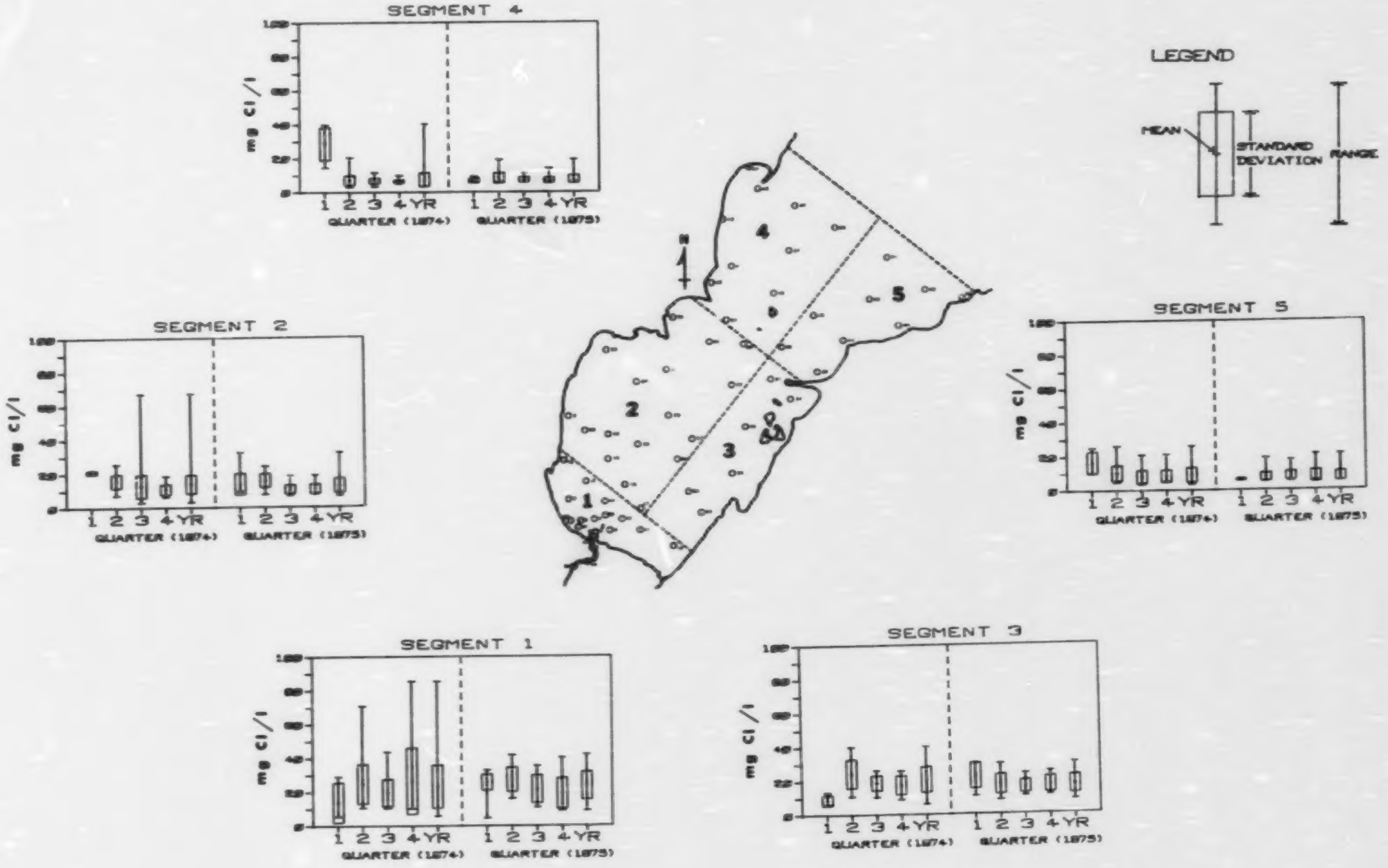


Figure 19. Data summary of filtered chloride (mg Cl/ℓ).

Quarterly and annual summaries of all pH data compiled for each segment and the total bay are shown in Table 12 and Figure 20.

Figure 21 shows typical variation of pH during a 24-hour period at one station (56) in the inner bay.

Alkalinity, total (tot. alk.)

The highest mean total alkalinity level of 183 mg $CaCO_3$/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 78 mg $CaCO_3$/ℓ was at station 49 (segment 4). The 1974-75 mean value of 99 mg $CaCO_3$/ℓ at station 14 was identical to the total bay mean.

Mean values by segment ranged from 81 mg $CaCO_3$/ℓ (segment 4, 1974) to 118 mg $CaCO_3$/ℓ (segment 1, 1975). The greatest annual range, 77 mg $CaCO_3$/ℓ - 173 mg $CaCO_3$/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 95 mg $CaCO_3$/ℓ in segment 2 was closest to the total bay mean of 92 mg $CaCO_3$/ℓ. In 1975 the mean of 98 mg $CaCO_3$/ℓ in segment 2 was closest to the bay mean of 92 mg $CaCO_3$/ℓ.

Quarterly and annual summaries of all tot. alkalinity data compiled for each segment and the total bay are shown in Table 13 and Figure 22.

Secchi Disc Depth

The highest mean Secchi depth level of 5.3 m during 1974-75 was recorded at station 51 (segment 5). The lowest of 0.4 m was at station 54 (river). The 1974-75 mean value of 1.6 m at station 61 was closest to the total bay mean of 1.8 m.

Mean values by segment ranged from 0.87 m (segment 1, 1974) to 3.6 m (segment 4, 1975). The greatest annual range, 0.5 m - 9.0 m, occurred in segment 5 (1974). In 1974 the mean value of 1.3 m in segment 2 was closest to the total bay mean of 1.8 m. In 1975 the mean of 1.5 m in segment 2 was closest to the bay mean of 2.1 m.

Results showing the variation by cruise (at two depths) of Secchi depth at selected stations are given in Table 14 and Figure 23. Quarterly and annual summaries of all Secchi depth data compiled for each segment and the total bay are shown in Table 15 and Figure 24.

Chlorophyll *a*, non-filterable (nf. chl. *a*)

The highest mean non-filterable chlorophyll *a* level of 42.87 μg chl. *a*/ℓ during 1974-75 was recorded at station 21 (segment 1). The lowest of 2.25 μg chl. *a*/ℓ was at station 50 (segment 4). The 1974-75 mean value of 15.25 μg chl. *a*/ℓ at station 32 was closest to the total bay mean of 15.37 μg chl. *a*/ℓ.

Mean values by segment ranged from 3.5 μg chl. *a*/ℓ (segment 4, 1974) to 33.3 μg chl. *a*/ℓ (segment 1, 1975). The greatest annual range, 4.2 μg chl. *a*/ℓ - 87.9 μg chl. *a*/ℓ, occurred in segment 1 (1975). In 1974 the mean value

TABLE 12. DATA SUMMARY OF pH PLOTTED IN FIGURE 20

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	8.60 ± .42	8.25 ± .30	8.61 ± .50	8.74 ± .30	8.43 ± .29
Range	7.21 - 9.58	7.90 - 8.80	7.21 - 9.58	7.86 - 9.22	7.88 - 9.02
# of Samples	164	6	77	50	31
Segment II					
Mean ± s.d.	8.58 ± .35	8.08 ± .14	8.65 ± .38	8.58 ± .31	8.38 ± .28
Range	6.88 - 9.40	7.98 - 8.18	6.88 - 9.40	7.78 - 9.18	7.96 - 8.92
# of Samples	240	2	118	82	38
Segment III					
Mean ± s.d.	8.80 ± .28	8.56 ± .40	8.87 ± .23	8.88 ± .23	8.58 ± .27
Range	7.93 - 9.33	7.93 - 8.86	8.30 - 9.33	8.48 - 9.18	8.24 - 8.85
# of Samples	50	5	23	14	8
Segment IV					
Mean ± s.d.	8.22 ± .33	7.97 ± .04	8.12 ± .43	8.35 ± .18	8.20 ± .17
Range	7.34 - 9.30	7.9 - 8.0	7.34 - 9.30	7.77 - 8.75	8.04 - 8.79
# of Samples	248	5	110	87	46
Segment V					
Mean ± s.d.	8.4 ± .4	8.0 ± .4	8.3 ± .5	8.5 ± .2	8.3 ± .2
Range	7.5 - 9.3	7.8 - 8.6	7.5 - 9.3	8.0 - 9.1	8.0 - 8.9
# of Samples	190	4	78	74	34
Total Bay					
Mean ± s.d.	8.45 ± .40	8.21 ± .35	8.45 ± .50	8.53 ± .29	8.33 ± .26
Range	6.88 - 9.58	7.80 - 8.86	6.88 - 9.58	7.77 - 9.22	7.88 - 9.02
# of Samples	892	22	406	307	157

1975

Segment 1					
Mean ± s.d.	8.7 ± .4	-	8.7 ± .4	8.8 ± .4	8.5 ± .3
Range	7.6 - 9.4	-	8.0 - 9.3	7.6 - 9.4	8.1 - 8.9
# of Samples	57	-	23	22	12
Segment II					
Mean ± s.d.	8.5 ± .3	-	8.4 ± .3	8.6 ± .2	8.3 ± .2
Range	7.9 - 9.1	-	7.9 - 9.1	8.0 - 9.0	8.1 - 8.9
# of Samples	198	-	80	73	45
Segment III					
Mean ± s.d.	8.8 ± .3	-	8.7 ± .3	8.9 ± .2	8.5 ± .3
Range	8.1 - 9.4	-	8.1 - 9.1	8.5 - 9.4	8.1 - 8.9
# of Samples	45	-	23	17	5
Segment IV					
Mean ± s.d.	8.3 ± .2	-	8.3 ± .3	8.5 ± .2	8.2 ± .2
Range	7.7 - 8.9	-	7.8 - 8.9	8.0 - 8.8	7.6 - 8.5
# of Samples	228	-	88	83	57
Segment V					
Mean ± s.d.	8.4 ± .3	-	8.4 ± .3	8.6 ± .2	8.2 ± .2
Range	7.6 - 9.1	-	7.9 - 9.0	8.0 - 9.1	7.6 - 8.7
# of Samples	182	-	72	64	46
Total Bay					
Mean ± s.d.	8.5 ± .3	-	8.4 ± .3	8.6 ± .3	8.3 ± .2
Range	7.6 - 9.4	-	7.8 - 9.3	7.6 - 9.4	7.6 - 8.9
# of Samples	710	-	286	259	165

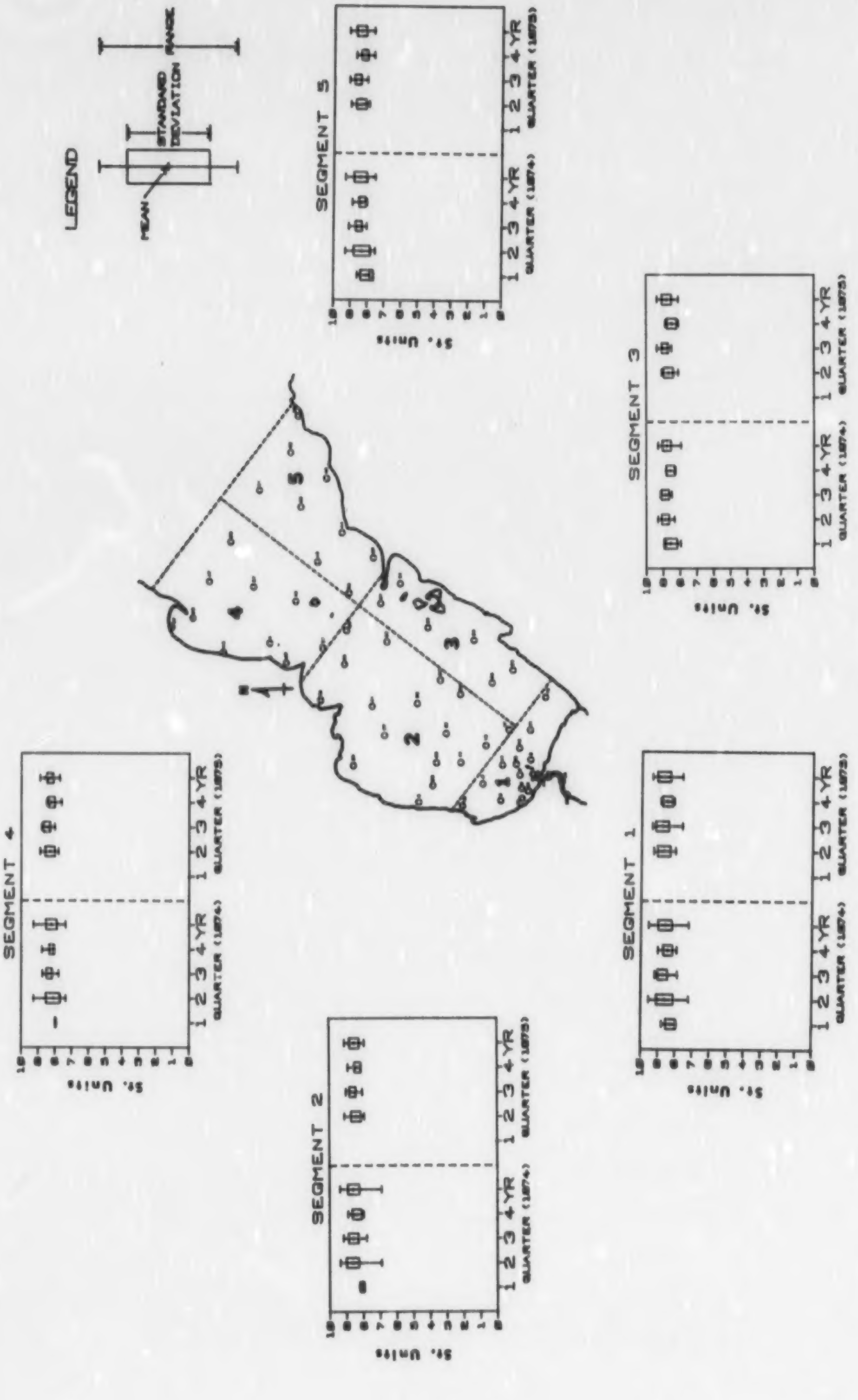


Figure 20. Data summary of pH.

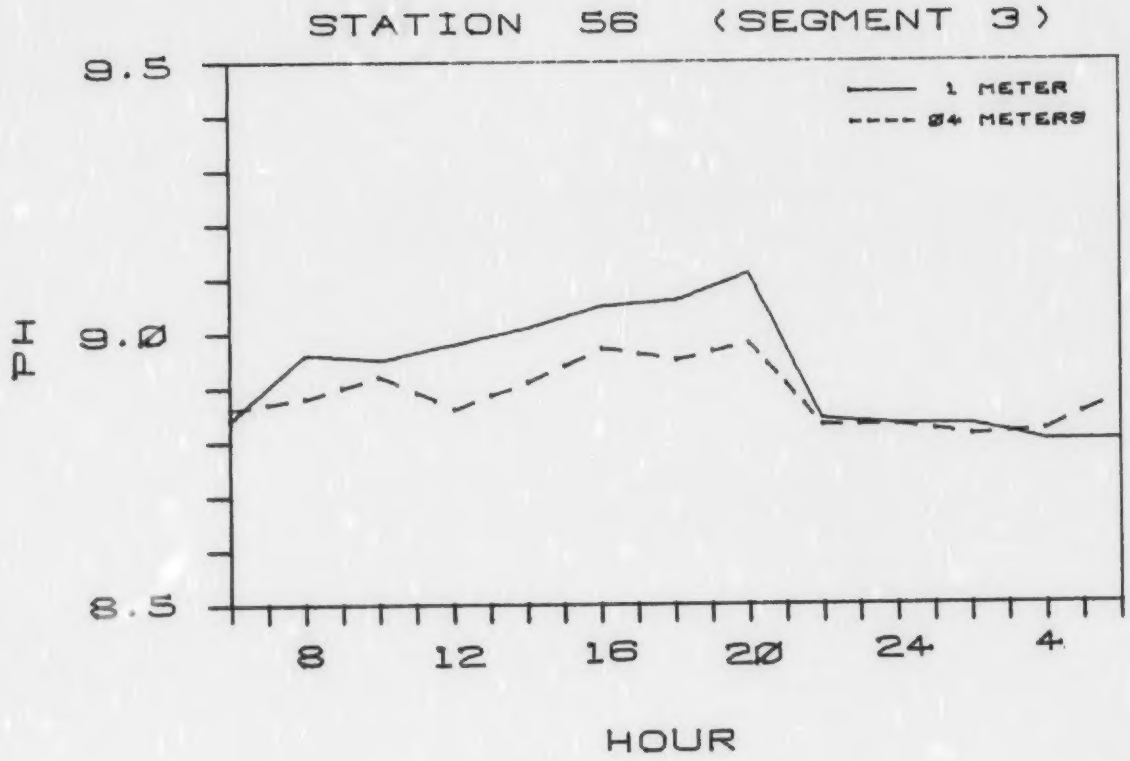


Figure 21. pH variation at station 56 during a diurnal survey (August 16-17, 1975).

TABLE 13. DATA SUMMARY OF TOTAL ALKALINITY (mg $CaCO_3/\ell$), PLOTTED IN FIGURE 22

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment I					
Mean ± s.d.	107 ± 18	112.5 ± 9.6	119.1 ± 20.5	98.01 ± 9.3	100.6 ± 13.5
Range	77 - 173	102.0 - 127.0	91.0 - 173.0	77.0 - 129.0	88 - 142
# of Samples	174	6	69	68	31
Segment II					
Mean ± s.d.	95 ± 10	95 ± 1	100 ± 11	91 ± 5	89 ± 4
Range	75 - 145	94 [illegible]	82 - 145	75 - 103	80 - 95
# of Samples	246	2	101	105	38
Segment III					
Mean ± s.d.	102 ± 12	110 ± 15	113 ± 10	94 ± 5	94 ± 5
Range	83 - 142	86 - 122	90 - 142	83 - 104	89 - 101
# of Samples	56	5	21	23	7
Segment IV					
Mean ± s.d.	81 ± 5	83 ± 5	83 ± 7	81 ± 4	80 ± 2
Range	70 - 104	77 - 91	70 - 104	72 - 93	75 - 86
# of Samples	234	5	90	93	46
Segment V					
Mean ± s.d.	84 ± 7	84 ± 2	84 ± 8	82 ± 4	86 ± 8
Range	74 - 115	81 - 86	75 - 115	75 - 96	74 - 102
# of Samples	178	4	68	72	34
Total Bay					
Mean ± s.d.	92 ± 15	99 ± 16	97 ± 19	88 ± 9	88 ± 11
Range	70 - 173	77 - 127	70 - 173	72 - 129	74 - 142
# of Samples	888	22	349	361	156

1975

Segment I					
Mean ± s.d.	118 ± 27	-	141 ± 16	92 ± 3	96 ± 8
Range	89 - 173	-	108 - 173	89 - 94	89 - 111
# of Samples	22	-	11	4	7
Segment II					
Mean ± s.d.	98 ± 13	-	108 ± 12	85 ± .5	89 ± 6
Range	80 - 131	-	85 - 131	85 - 86	80 - 107
# of Samples	96	-	48	5	43
Segment III					
Mean ± s.d.	106 ± 10	-	116 ± 14	88 ± 7	94
Range	82 - 136	-	98 - 136	82 - 96	94
# of Samples	60	-	10	5	1
Segment IV					
Mean ± s.d.	83 ± 8	-	86 ± 8	-	79 ± 5
Range	67 + 102	-	67 - 102	-	74 - 98
# of Samples	107	-	57	-	50
Segment V					
Mean ± s.d.	85 ± 9	-	85 ± 10	84 ± 2	84 ± 9
Range	63 - 111	-	63 - 111	81 - 86	75 - 111
# of Samples	86	-	46	5	35
Total Bay					
Mean ± s.d.	92 ± 16	-	97 ± 19	87 ± 4	86 ± 9
Range	63 - 173	-	63 - 173	81 - 96	74 - 111
# of Samples	371	-	172	19	136

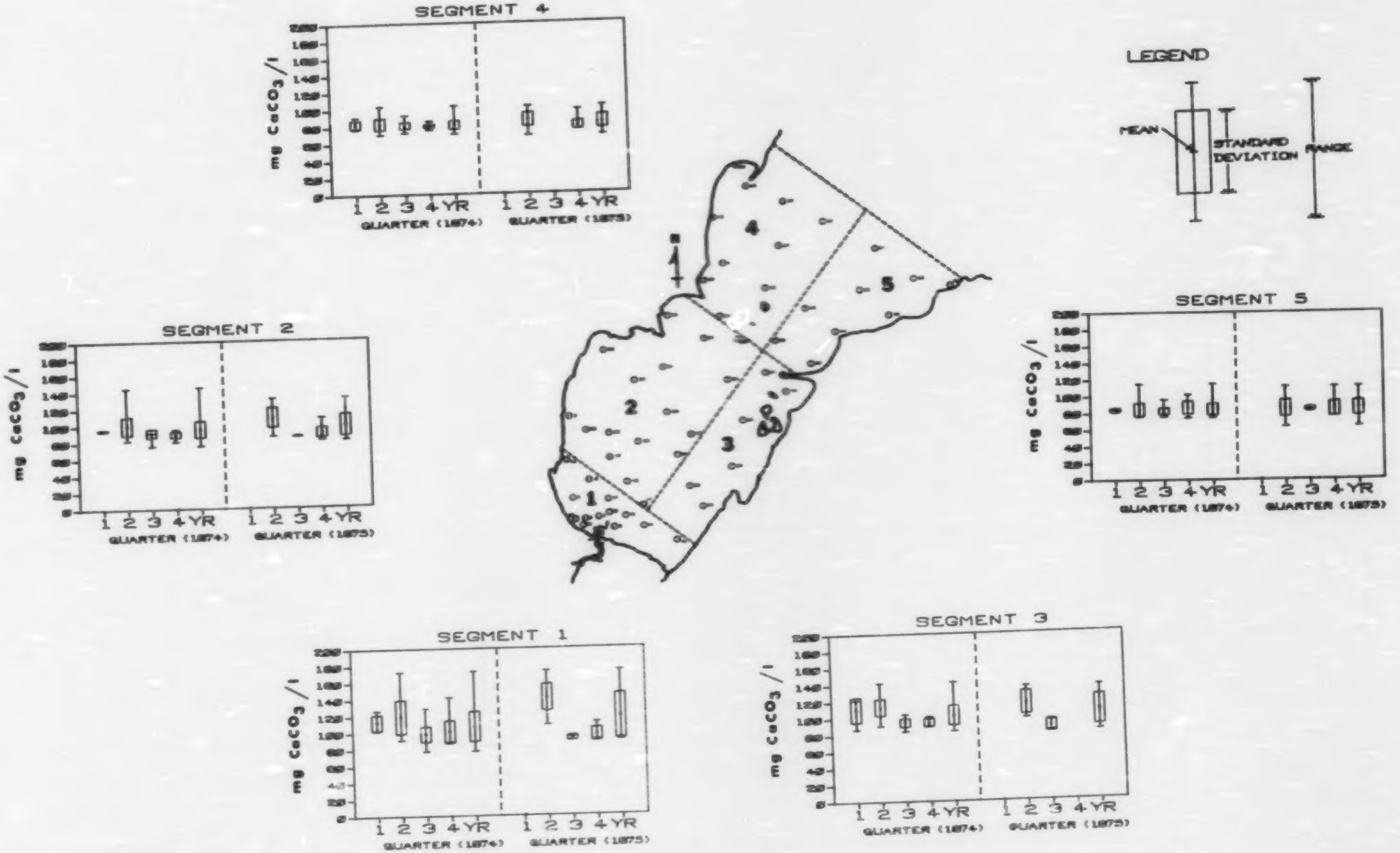


Figure 22. Data summary of total alkalinity (mg CaCO$_3$/ℓ).

TABLE 14. SECCHI DISC DEPTH (m) AT SELECTED STATIONS, PLOTTED IN FIGURE 23

Station Number	Location	Depth In Meters	Mean*	(Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	0.5	(0.2-1.5)	0.3	74-6-18	74-2-21
		8					
8	Segment I	1	0.9	(0.5-1.6)	0.3	74-4-17	75-7-31
		3					
35	Segment II	1	2.0	(1.0-3.5)	0.6	74-10-6	75-7-29
		10					
34	Segment III	1	0.9	(0.5-2.3)	0.6	74-6-19	75-2-19
		3					
49	Segment IV	1	5.1	(1.0-7.5)	1.5	75-6-26	75-5-1
		20					
51	Segment V	1	5.3	(1.7-8.5)	1.8	75-4-10	74-6-19
		28					

*Mid-winter data included for 1 m depth only.

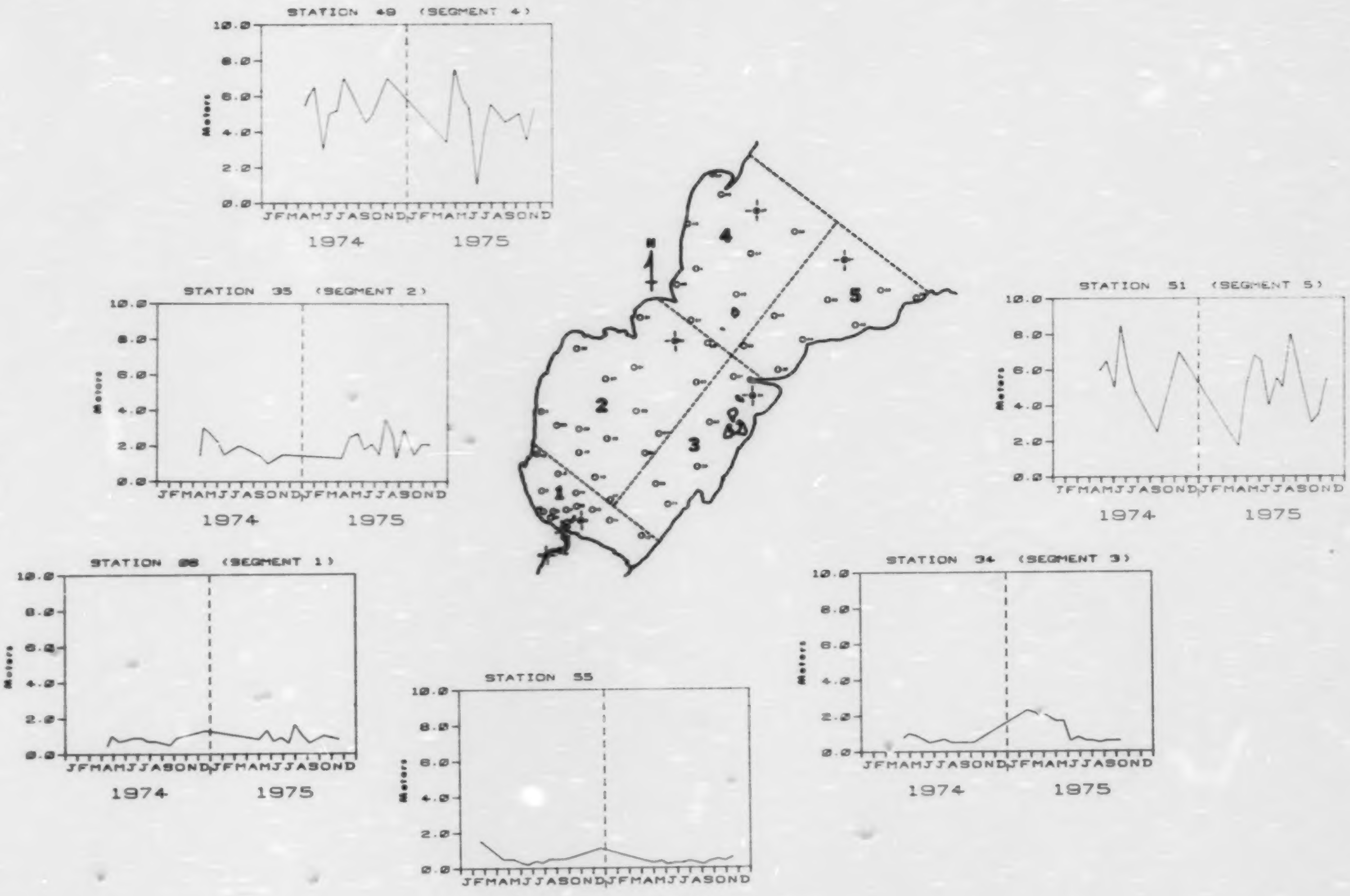


Figure 23. Secchi disc depth (m) at selected stations (-•-).

TABLE 15. DATA SUMMARY OF SECCHI DISC DEPTH (m), PLOTTED IN FIGURE 24

1974

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-A)	4th (S-D)
Segment I					
Mean ± s.d.	.87 ± .35	3.00	.82 ± .30	.80 ± .29	1.02 ± .27
Range	.10 - 3.00	3.00	.10 - 1.80	.30 - 1.70	.60 - 1.50
# of Samples	131	1	59	46	25
Segment II					
Mean ± s.d.	1.3 ± .5	—	1.4 ± .6	1.2 ± .4	1.1 ± .4
Range	.3 - 3.0	—	.3 - 3.0	.4 - 2.7	.5 - 1.9
# of Samples	156	—	73	59	24
Segment III					
Mean ± s.d.	1.0 ± .7	3.2 ± 1.4	.8 ± .3	1.0 ± .4	.7 ± .3
Range	.4 - 4.0	1.5 - 4.0	.5 - 1.4	.5 - 2.0	.4 - 1.3
# of Samples	57	3	25	19	10
Segment IV					
Mean ± s.d.	3.4 ± 1.6	—	3.5 ± 1.6	3.2 ± 1.5	3.6 ± 1.9
Range	1.0 - 7.5	—	1.0 - 7.5	1.0 - 7.0	1.2 - 7.0
# of Samples	100	—	43	40	17
Segment V					
Mean ± s.d.	2.7 ± 1.9	—	2.8 ± 1.8	2.9 ± 2.0	2.1 ± 1.7
Range	.5 - 9.0	—	.5 - 8.5	.7 - 9.0	.7 - 7.0
# of Samples	82	—	36	35	11
Total Bay					
Mean ± s.d.	1.8 ± 1.5	3.1 ± 1.2	1.8 ± 1.5	1.8 ± 1.5	1.7 ± 1.4
Range	.1 - 9.0	1.5 - 4.0	.1 - 8.5	.3 - 9.0	.4 - 7.0
# of Samples	526	4	236	199	87

1975

Segment I					
Mean ± s.d.	.9 ± .4	1.5 ± .8	.8 ± .3	.8 ± .3	.8 ± .2
Range	.3 - 3.0	.5 - 3.0	.5 - 1.3	.3 - 1.6	.5 - 1.0
# of Samples	50	7	17	18	8
Segment II					
Mean ± s.d.	1.5 ± .7	2.6 ± .2	1.5 ± .6	1.5 ± .8	1.3 ± .5
Range	.3 - 5.0	2.4 - 2.7	.4 - 2.7	.3 - 5.0	.6 - 2.1
# of Samples	115	2	45	43	25
Segment III					
Mean ± s.d.	1.4 ± .7	2.5 ± .4	1.6 ± .6	1.0 ± .5	.9 ± .2
Range	.5 - 3.0	2.3 - 3.0	.6 - 2.6	.5 - 2.2	.6 - 1.1
# of Samples	42	3	19	16	4
Segment IV					
Mean ± s.d.	3.6 ± 1.5	4.5	3.8 ± 1.5	3.7 ± 1.7	3.2 ± 1.3
Range	1.0 - 8.0	4.5	1.0 - 7.5	1.2 - 8.0	1.3 - 5.3
# of Samples	86	1	34	31	20
Segment V					
Mean ± s.d.	3.0 ± 1.6	-	3.6 ± 1.4	2.7 ± 1.9	2.4 ± 1.3
Range	.8 - 8.0	-	.9 - 6.8	.8 - 8.0	.9 - 5.5
# of Samples	67	-	27	23	17
Total Bay					
Mean ± s.d.	2.1 ± 1.5	2.1 ± 1.0	2.3 ± 1.5	2.0 ± 1.6	1.9 ± 1.3
Range	.3 - 8.0	.5 - 4.5	.4 - 7.5	.3 - 8.0	.5 - 5.5
# of Samples	360	13	142	131	74

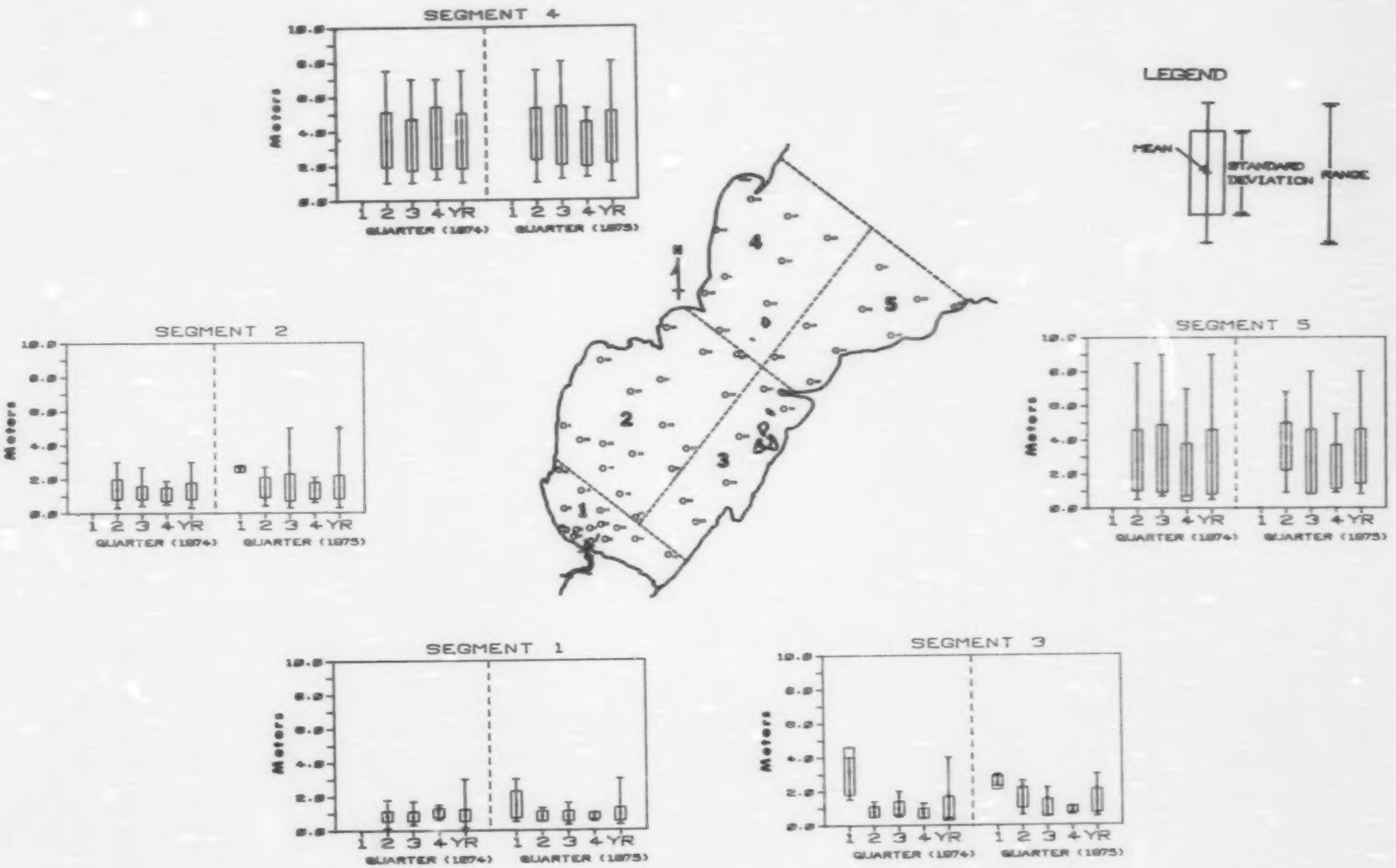


Figure 24. Data summary of Secchi disc depth (m).

of 16.26 μg chl. *a*/ℓ in segment 2 was closest to the total bay mean of 15.7 μg chl. *a*/ℓ. In 1975 the mean of 12.9 μg chl. *a*/ℓ in segment 2 was closest to the bay mean of 11.9 μg chl. *a*/ℓ.

Results showing the variation by cruise (at two depths) of nf. chlorophyll *a* at selected stations are given in Table 16 and Figure 25. Quarterly and annual summaries of all chlorophyll *a* data compiled for each segment and the total bay are shown in Table 17 and Figure 26.

Figure 27 shows typical variation of nf. chlorophyll *a* during a 24-hour period at one station (56) in the inner bay. Twice-weekly chlorophyll *a* data from four intake plants (plotted in Figure 28) are compared in Table 18 to regular cruise data for the same sites.

Carbon, unfiltered organic (u. org. C)

The highest mean unfiltered organic carbon level of 13.2 mg C/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 2.4 mg C/ℓ was at station 57 (segment 4). The 1974-74 mean value of 5.9 mg C/ℓ at station 22 was closest to the total bay mean of 6.1 mg C/ℓ.

Mean values by segment ranged from 3.5 mg C/ℓ (segment 4, 1974) to 8.1 mg C/ℓ (segment 1, 1974). The greatest annual range, 3.6 mg C/ℓ - 34.5 mg C/ℓ, occurred in segmnet 1 (1974). In 1974 the mean value of 5.8 mg C/ℓ in segment 2 was closest to the total bay mean of 5.6 mg C/ℓ. In 1975 the mean of 5.4 mg C/ℓ in segment 2 was closest to the bay mean of 5.1 mg C/ℓ.

Quarterly and annual summaries of all u. org. carbon data compiled for each segment and the total bay are shown in Table 19 and Figure 29.

Carbon, filtered organic (f. org. C)

The highest mean filtered organic carbon level of 11.4 mg C/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 2.3 mg C/ℓ was at station 57 (segment 4). The 1974-75 mean value of 4.9 mg C/ℓ at station 21 was identical to the total bay mean of 4.9 mg C/ℓ.

Mean values by segment ranged from 3.3 mg C/ℓ (segment 4, 1975) to 6.3 mg C/ℓ (segment 3, 1974, and segment 1, 1975). The greatest annual range, 3.5 mg C/ℓ - 16.7 mg C/ℓ, occurred in segment 1 (1975). In 1974 the mean value of 4.5 mg C/ℓ in segment 2 was closest to the total bay mean of 4.4 mg C/ℓ. In 1975 the mean of 4.5 mg C/ℓ in segment 2 was closest to the bay mean of 4.3 mg C/ℓ.

Quarterly and annual summaries of all f. org. carbon data compiled for each segment and the total bay are shown in Table 20 and Figure 30.

Solids, unfiltered total (u. tot. sol.)

The highest mean unfiltered total solids level of 456.8 mg/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 125.3 mg/ℓ was at sta-

TABLE 16. NON-FILTERABLE CHLOROPHYLL *a* (μg chl. *a*/ℓ) AT SELECTED STATIONS, PLOTTED IN FIGURE 25

Station Number	Location	Depth In Meters	Mean* (Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	26.64 (.67-65.10)	16.62	74-2-21	74-7-8
		8	23.73 (4.01-46.50)	14.02	75-9-3	75-10-27
8	Segment I	1	33.24 (9.38-76.30)	17.01	75-7-31	75-7-16
		3	29.02 (7.46-57.40)	15.05	75-7-31	75-7-16
35	Segment II	1	8.24 (2.25-25.50)	5.08	75-10-27	75-9-3
		10	8.96 (3.37-27.60)	6.44	75-9-23	75-9-3
34	Segment III	1	25.86 (4.25-68.50)	16.22	75-2-19	75-7-31
		3	33.17 (11.20-50.70)	12.74	75-5-22	75-7-31
49	Segment IV	1	2.27 (0.64-12.00)	2.24	74-7-9	75-6-26
		20	3.04 (1.34-5.93)	1.33	75-5-21	75-7-15
51	Segment V	1	1.91 (0.72-6.01)	1.19	74-7-9	75-10-10
		28	2.92 (1.04-5.53)	1.58	75-10-10	75-7-15

*Mid-winter data included for 1 m depth only.

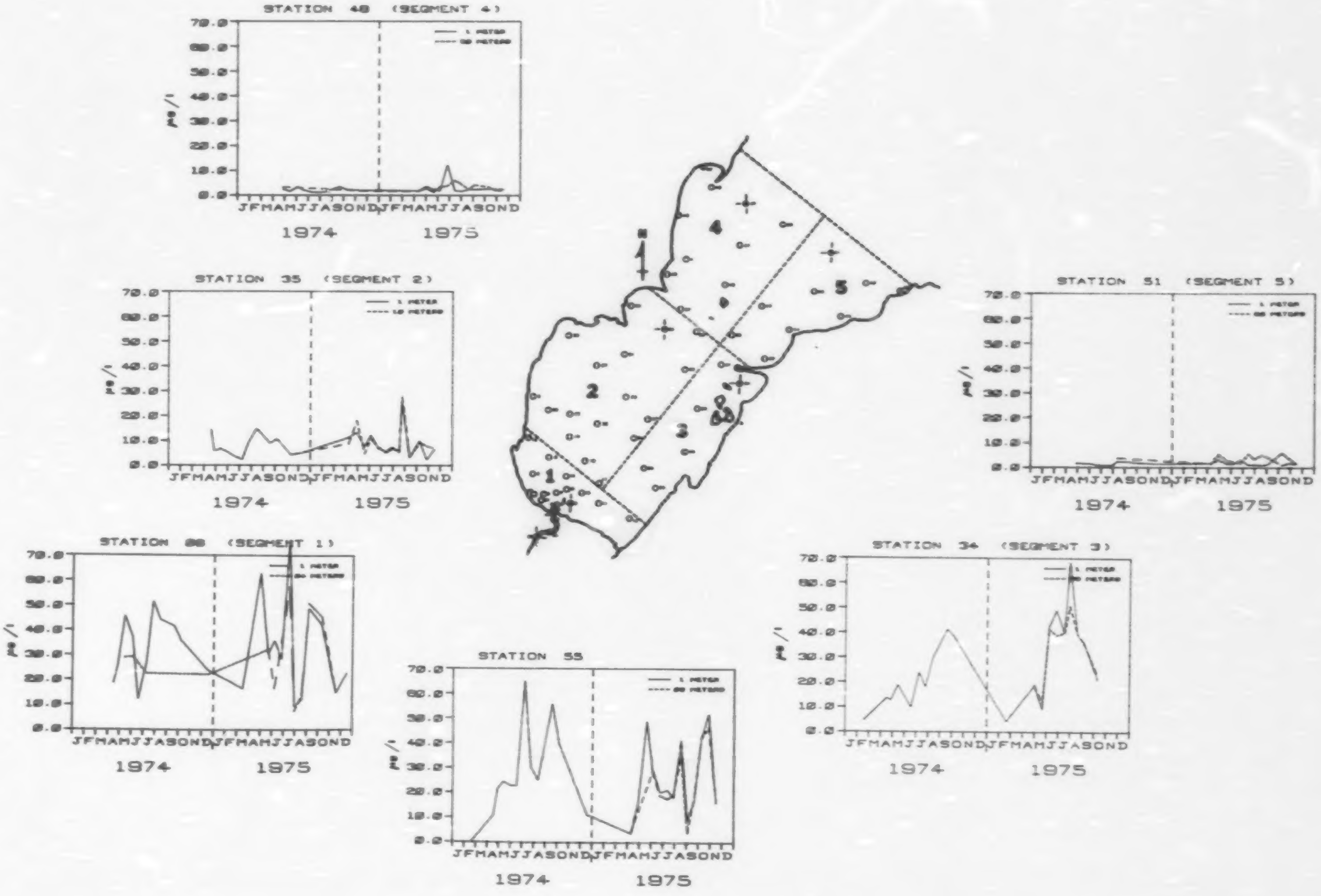


Figure 25. Non-filterable chlorophyll *a* (µg chl. *a*/ℓ) at selected stations (+).

TABLE 17. DATA SUMMARY OF NON-FILTERABLE CHLOROPHYLL *a* (μg chl. *a*/ℓ), PLOTTED IN FIGURE 26

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment I					
Mean ± s.d.	29.01±14.88	16.11 ± 13.8	27.59 ± 15.10	34.09 ± 15.91	25.18 ± 9.9
Range	1.07-74.40	4.33 - 31.40	1.07 - 74.40	9.71 - 68.30	9.31 - 52.3
# of Samples	152	3	68	50	31
Segment II					
Mean ± s.d.	16.76±10.37	8.82 ± 1.47	14.55 ± 9.59	19.85 ± 11.01	16.31 ± 9.5
Range	2.33-45.70	7.78 - 9.86	2.73 - 45.70	2.33 - 45.40	4.33 - 32.1
# of Samples	178	2	75	64	37
Segment III					
Mean ± s.d.	24.85±13.4	9.25 ± 5.85	22.30 ± 11.53	32.8 ± 12.8	25.5 ± 13.4
Range	4.41-58.50	4.41 - 18.9	9.78 - 44.7	12.8 - 58.5	8.12 - 43.1
# of Samples	54	5	22	16	11
Segment IV					
Mean ± s.d.	3.52 ± 2.34	3.71 ± 4.23	3.21 ± 2.12	3.59 ± 2.52	3.89 ± 2.28
Range	.40 - 11.50	.88 - 8.58	.88 - 10.90	.40 - 11.50	1.28 - 9.38
# of Samples	138	3	54	47	34
Segment V					
Mean ± s.d.	7.69 + 8.81	3.42 ± 1.76	7.30 ± 5.87	7.68 ± 11.09	9.16 ± 10.1
Range	.32 - 57.40	2.25 - 5.45	.88 - 25.70	.64 - 57.40	.32 - 36.60
# of Samples	128	3	55	46	24
Total Bay					
Mean ± s.d.	15.7±14.3	8.4 ± 7.7	14.7 ± 13.5	18.0 ± 16.4	14.7 ± 12.2
Range	.32 - 74.4	.88 - 31.4	.88 - 74.4	.40 - 68.3	.32 - 52.3
# of Samples	650	16	274	223	137

1975

Segment I					
Mean ± s.d.	33.3 ± 20.5	19.2 ± 7.9	40.0 ± 18.5	37.4 ± 25.4	24.4 ± 10.1
Range	4.2 - 87.9	4.2 - 35.4	11.2 - 77.9	5.7 - 87.9	14.4 - 45.4
# of Samples	74	10	23	27	14
Segment II					
Mean ± s.d.	12.9 ± 7.4	6.7 ± 5.7	11.3 ± 6.5	15.2 ± 8.8	13.5 ± 5.2
Range	1.4 - 41.1	1.4 - 20.1	3.0 - 41.1	1.8 - 39.8	2.3 - 28.6
# of Samples	209	12	78	73	46
Segment III					
Mean ± s.d.	24.0 ± 14.8	8.6 ± 3.8	19.4 ± 14.0	32.5 ± 15.0	25.4 ± 6.2
Range	4.1 - 68.5	4.3 - 13.6	4.0 - 46.8	6.0 - 68.5	17.3 - 36.4
# of Samples	53	5	21	19	8
Segment IV					
Mean ± s.d.	4.2 ± 4.1	1.7 ± 1.2	4.1 ± 3.7	4.7 ± 5.1	4.1 ± 3.1
Range	.3 - 25.3	.3 - 3.9	.8 - 19.	.9 - 25.3	1.4 - 15.1
# of Samples	228	6	90	75	57
Segment V					
Mean ± s.d.	6.5 ± 6.7	1.3 ± .6	4.1 ± 2.9	9.0 ± 9.5	7.4 ± 5.0
Range	.6 - 38.8	.6 - 2.3	1.0 - 16.5	.8 - 38.8	1.0 - 21.5
# of Samples	186	6	71	63	46
Total Bay					
Mean ± s.d.	11.9 ± 13.4	8.5 ± 8.3	10.5 ± 13.0	14.8 ± 16.2	10.6 ± 8.7
Range	.3 - 87.9	.3 - 35.4	.8 - 77.9	.8 - 87.9	1.0 - 45.4
# of Samples	750	39	283	257	171

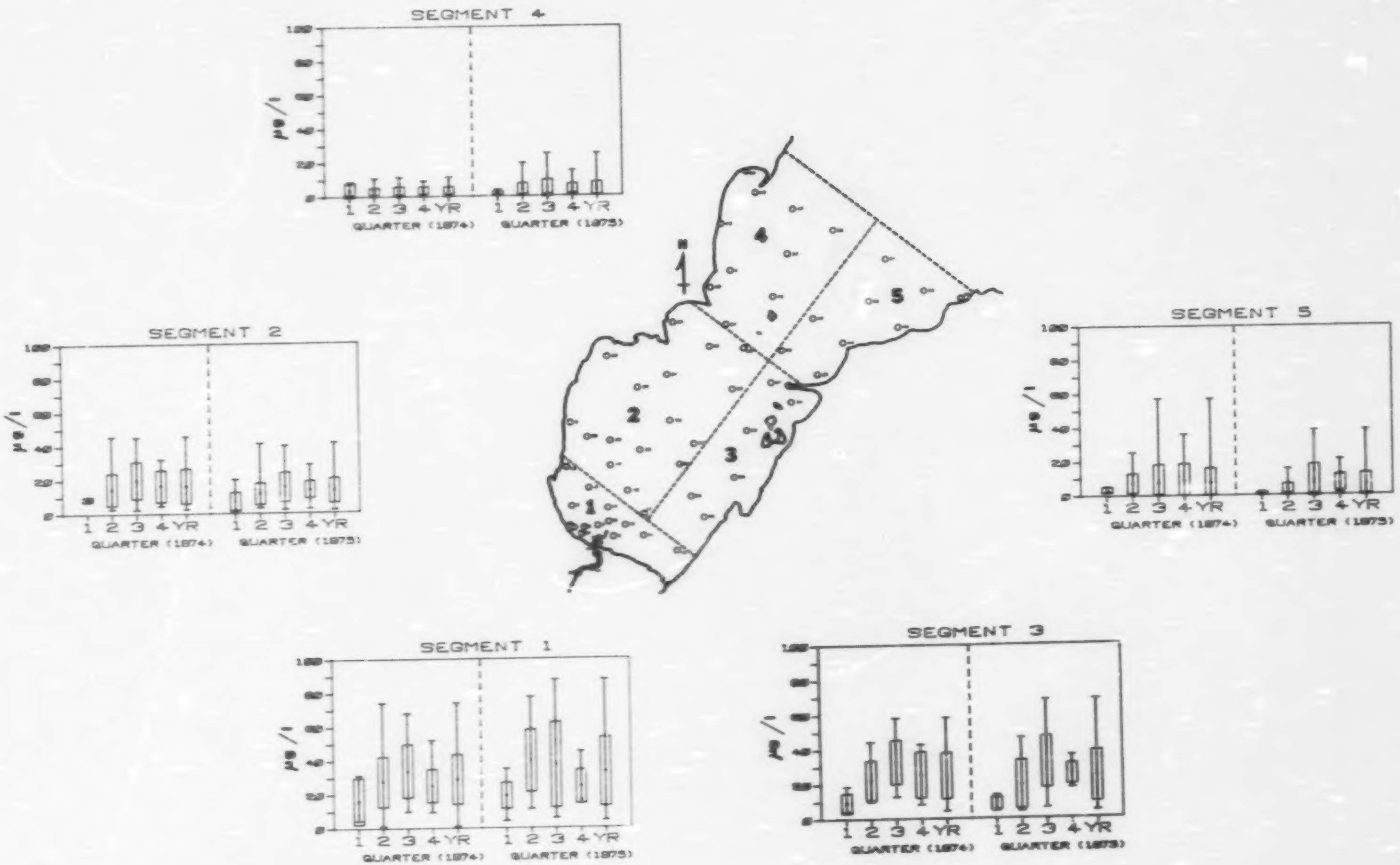


Figure 26. Data summary of non-filterable chlorophyll *a* (µg chl. *a*/ℓ).

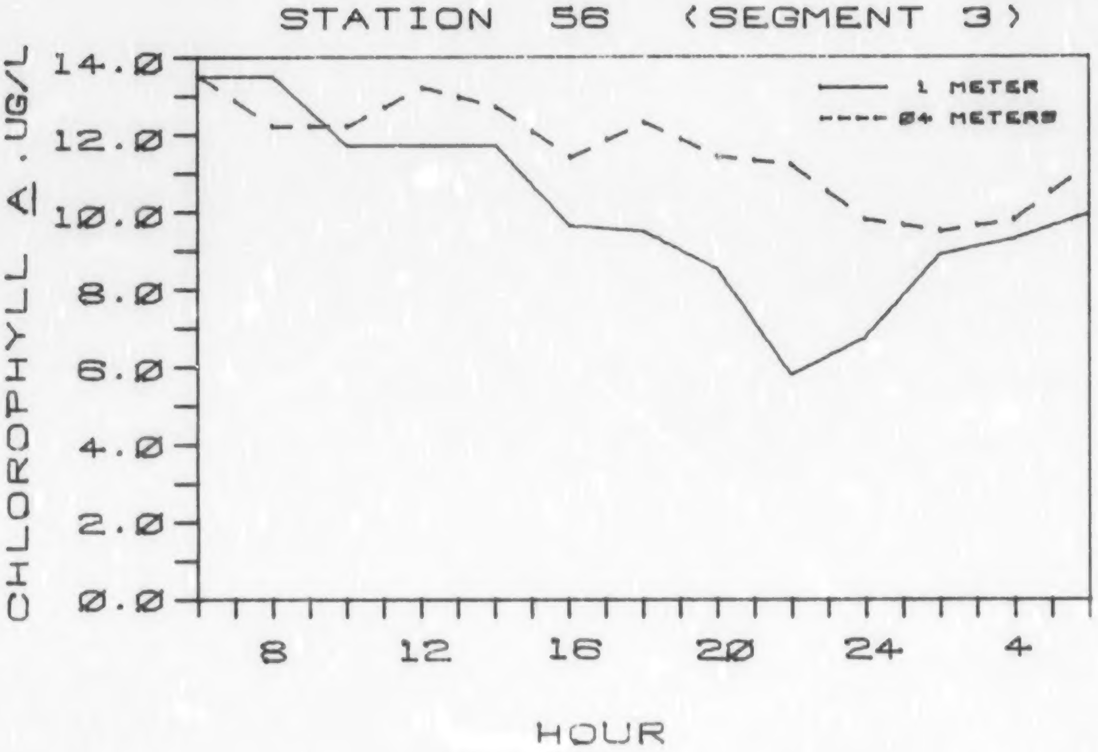


Figure 27. Non-filterable chlorophyll *a* (μg chl. *a*/ℓ) variation at station 56 during a diurnal survey (August 16-17, 1975).

TABLE 18. MEAN NON-FILTERABLE CHLOROPHYLL *a* VALUES (μg chl. *a*/ℓ) FROM CRUISE (SB) AND INTAKE PLANT (SBI) SAMPLES, PLOTTED IN FIGURE 28

		Station							
		Saginaw River		Kawkawlin		Pinconning		Whitestone Point	
	Month	SB 1	SBI 1	SB 2	SBI 2	SB 3	SBI 3	SB 4	SBI 4
1974	1	--	--	--	3.3	--	3.7	--	1.4
	2	--	--	--	4.5	4.4	7.4	--	1.7
	3	--	--	--	5.3	--	10.0	--	3.3
	4	18.5	17.1	23.3	15.2	34.6	25.2	1.5	2.7
	5	23.7	20.6	20.4	25.0	28.4	20.7	--	4.9
	6	23.3	12.0	13.5	6.1	8.5	9.1	2.7	2.0
	7	43.1	45.9	22.7	15.5	22.2	16.9	1.8	3.8
	8	62.5	54.2	32.9	31.2	38.8	43.2	4.8	4.2
	9	55.0	72.8	--	32.3	27.6	27.1	2.1	5.3
	10	37.0	38.2	31.9	18.5	24.9	18.8	3.6	3.6
	11	--	19.8	16.8	11.9	--	19.9	3.0	1.7
	12	10.9	10.1	--	18.8	--	11.7	--	1.4
1975	1	--	7.9	--	13.7	--	9.8	--	1.7
	2	2.7	3.7	--	6.7	4.6	3.2	--	1.4
	3	4.7	4.3	10.8	3.0	--	5.9	--	1.9
	4	8.3	8.9	56.4	11.2	9.5	15.4	1.5	3.8
	5	40.5	26.6	21.0	25.5	28.5	14.9	2.6	2.6
	6	16.7	22.8	37.0	16.0	37.4	27.2	4.6	3.4
	7	40.9	34.7	49.8	23.3	30.9	37.0	2.1	5.7
	8	94.5	67.4	17.1	19.6	13.9	34.3	--	3.5
	9	10.0	22.8	43.7	45.0	29.8	37.8	8.7	5.7
	10	38.5	--	22.8	21.0	28.3	28.6	3.5	3.9
	11	15.0	--	21.8	17.9	14.6	17.9	2.8	5.3
	12	--	--	23.1	23.3	--	22.5	--	--

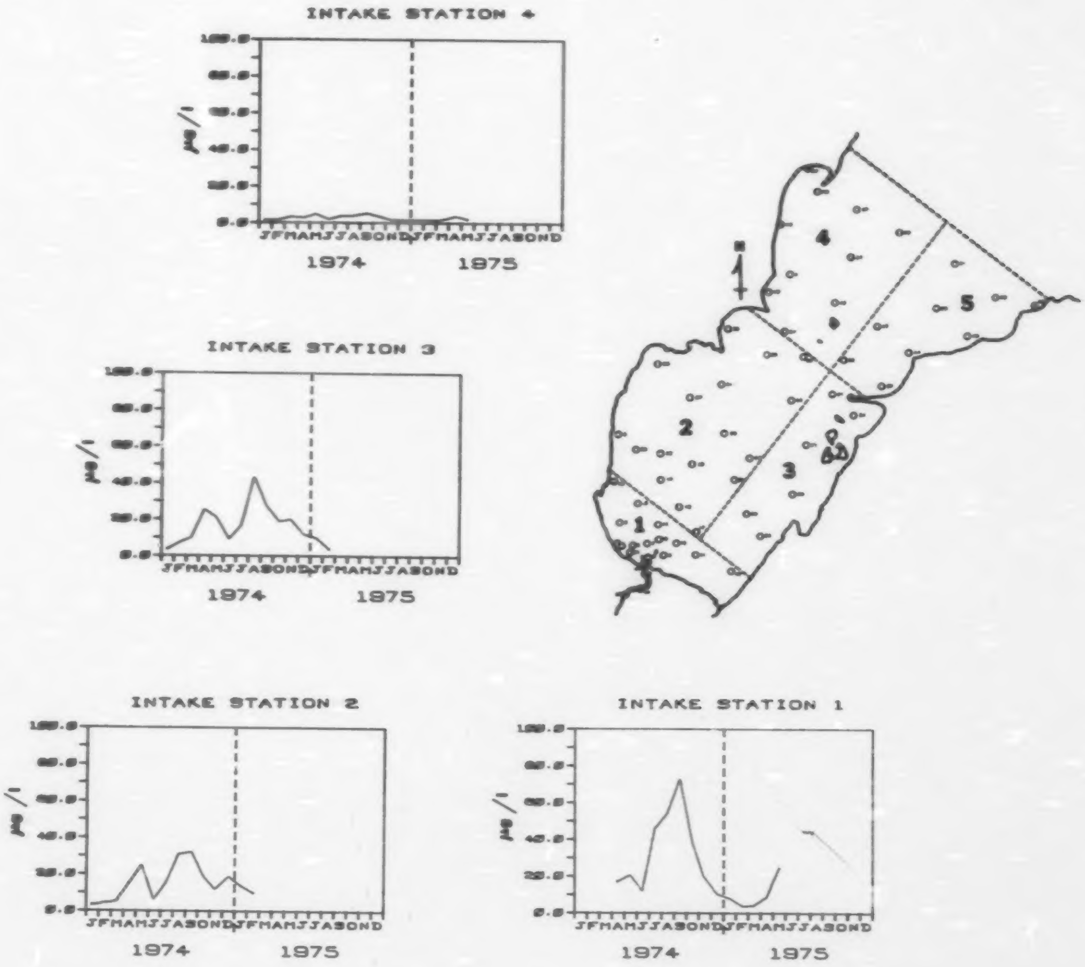


Figure 28. Non-filterable chlorophyll *a* (µg chl. *a*/ℓ) in twice-weekly samples from water intake plants (equivalent to stations 1, 2, 3, 4).

TABLE 19. DATA SUMMARY OF UNFILTERED ORGANIC CARBON (mg C/ℓ) PLOTTED IN FIGURE 29

		Yearly Gross	Quarters			
			1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
1974	**Segment I**					
	Mean ± s.d.	8.1 ± 5.3	-	12.4 ± 6.3	-	5.4 ± 1.6
	Range	3.6 - 34.5	-	5.5 - 34.5	-	3.6 - 11.5
	# of Samples	61	-	23	-	38
	Segment II					
	Mean ± s.d.	5.8 ± 2.5	-	7.8 ± 2.6	-	4.6 ± 1.5
	Range	2.6 - 16.3	-	5.1 - 16.3	-	2.6 - 9.1
	# of Samples	76	-	28	-	48
	Segment III					
	Mean ± s.d.	8.6 ± 3.3	-	11.5 ± 2.6	-	6.7 ± 2.1
	Range	2.8 - 16.4	-	9.1 - 16.4	-	2.8 - 9.2
	# of Samples	18	-	7	-	11
	Segment IV					
	Mean ± s.d.	3.5 ± 1.6	-	4.5 ± 1.7	-	3.0 ± 1.4
	Range	1.9 - 10.0	-	2.7 - 7.5	-	1.9 - 10.0
	# of Samples	63	-	21	-	42
	Segment V					
	Mean ± s.d.	4.4 ± 2.5	-	5.5 ± 3.3	-	3.7 ± 1.6
	Range	2.2 - 14.9	-	2.9 - 14.9	-	2.2 - 9.8
	# of Samples	50	-	20	-	30
	Total Bay					
	Mean ± s.d.	5.6 ± 3.6	-	7.9 ± 4.7	-	4.3 ± 1.8
	Range	1.9 - 34.5	-	2.7 - 34.5	-	1.9 - 11.5
	# of Samples	268	-	99	-	169
1975	**Segment I**					
	Mean ± s.d.	7.9 ± 2.7	6.0 ± 0.8	8.5 ± 1.9	9.4 ± 3.4	6.3 ± 1.4
	Range	4.1 - 15.7	4.1 - 7.0	4.8 - 11.4	4.1 - 15.7	4.3 - 9.8
	# of Samples	76	10	24	24	18
	Segment II					
	Mean ± s.d.	5.4 ± 1.9	4.2 ± 0.9	5.6 ± 1.6	6.1 ± 2.4	4.8 ± 1.3
	Range	2.6 - 14.0	3.2 - 6.0	2.6 - 10.2	3.1 - 14.0	2.8 - 8.6
	# of Samples	142	13	56	42	31
	Segment III					
	Mean ± s.d.	6.7 ± 2.4	6.7 ± 2.5	5.4 ± 2.0	8.3 ± 2.3	6.6 ± 1.8
	Range	1.8 - 12.9	4.8 - 11.0	1.8 - 8.8	5.4 - 12.9	4.7 - 9.8
	# of Samples	47	5	19	16	7
	Segment IV					
	Mean ± s.d.	3.6 ± 1.5	2.8 ± .41	3.4 ± 1.1	4.3 ± 2.1	3.1 ± 0.7
	Range	2.1 - 13.1	2.2 - 3.4	2.1 - 7.7	2.3 - 13.1	2.3 - 6.1
	# of Samples	130	6	55	39	30
	Segment V					
	Mean ± s.d.	4.0 ± 1.6	3.0 ± 0.4	3.2 ± 0.9	5.0 ± 1.6	4.3 ± 1.8
	Range	2.2 - 10.2	2.4 - 3.3	2.7 - 6.6	2.6 - 8.4	2.4 - 10.2
	# of Samples	92	5	39	27	21
	Total Bay					
	Mean ± s.d.	5.1 ± 2.4	4.5 ± 1.8	4.8 ± 2.2	6.2 ± 3.0	4.6 ± 1.8
	Range	1.8 - 15.7	2.2 - 11.0	1.8 - 11.4	2.3 - 15.7	2.3 - 10.2
	# of Samples	487	39	193	148	107

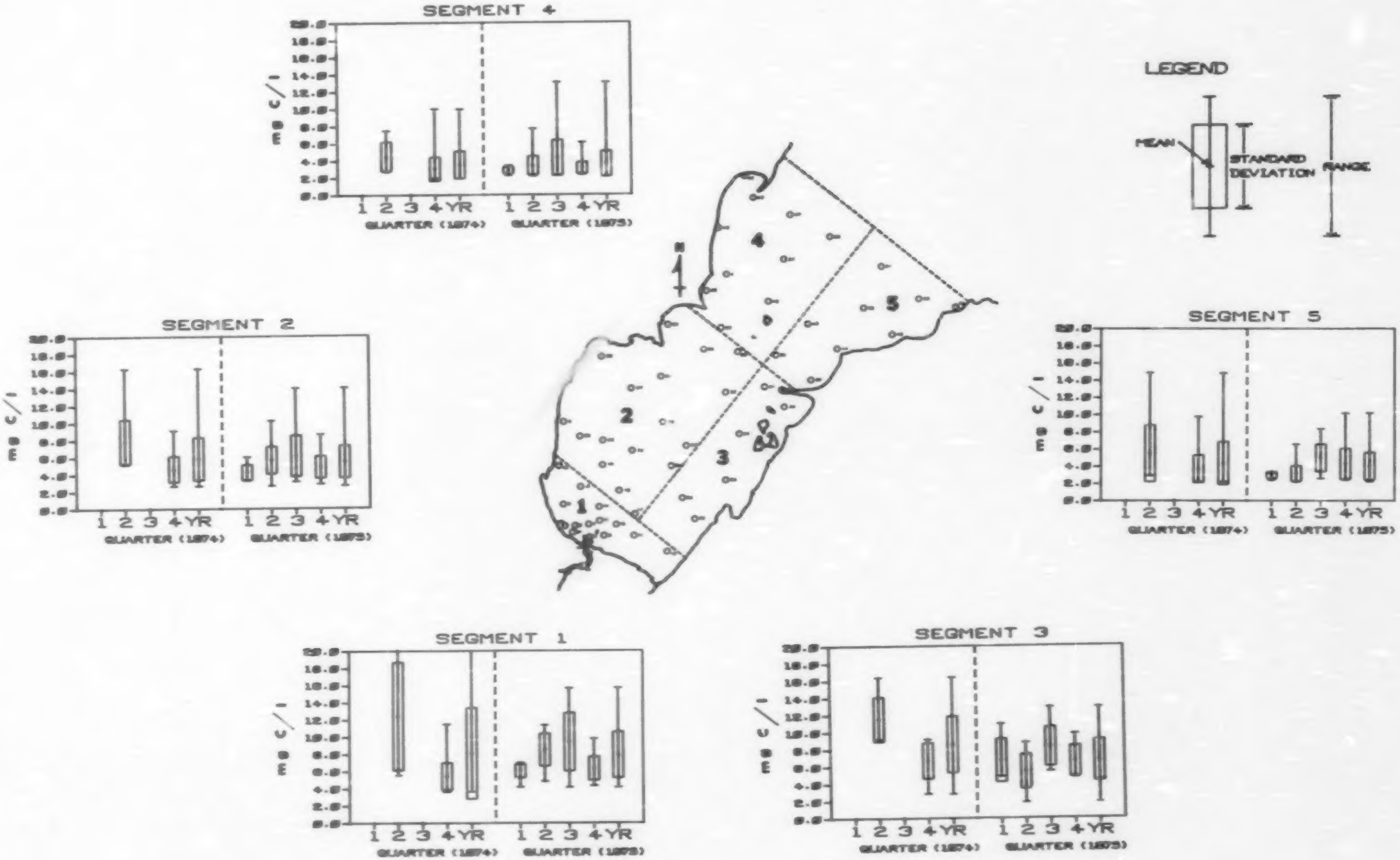


Figure 29. Data summary of unfiltered organic carbon (mg C/ℓ).

TABLE 20. DATA SUMMARY OF FILTERED ORGANIC CARBON (mg C/ℓ) PLOTTED IN FIGURE 30

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	5.6 ± 2.2	-	7.3 ± 2.5	-	4.5 ± 0.9
Range	1.0 - 12.6	-	1.0 - 12.6	-	2.9 - 7.0
# of Samples	61	-	23	-	38
Segment II					
Mean ± s.d.	4.5 ± 1.7	-	6.1 ± 1.8	-	3.6 ± 0.6
Range	2.4 - 12.1	-	3.8 - 12.1	-	2.4 - 4.8
# of Samples	76	-	28	-	48
Segment III					
Mean ± s.d.	6.3 ± 2.7	-	8.9 ± 2.5	-	4.6 ± 0.9
Range	2.7 - 13.0	-	5.6 - 15	-	2.7 - 5.7
# of Samples	18	-	7	-	11
Segment IV					
Mean ± s.d.	3.4 ± 1.5	-	4.6 ± 2.0	-	2.8 ± 0.4
Range	2.3 - 9.3	-	2.4 - 9.3	-	2.3 - 3.7
# of Samples	62	-	20	-	42
Segment V					
Mean ± s.d.	3.7 ± 1.6	-	4.6 ± 2.1	-	3.2 ± 0.7
Range	2.2 - 10.0	-	2.2 - 10.0	-	2.2 - 5.1
# of Samples	50	-	20	-	30
Total Bay					
Mean ± s.d.	4.4 ± 2.0	-	5.9 ± 2.5	-	3.6 ± 1.0
Range	1.0 - 13.0	-	1.0 - 13.0	-	2.2 - 7.3
# of Samples	267	-	98	-	169

1975

Segment 1					
Mean ± s.d.	6.3 ± 2.8	5.0 ± 0.6	6.6 ± 1.6	7.8 ± 4.1	4.7 ± 1.1
Range	3.5 - 16.7	3.6 - 5.5	4.1 - 9.9	3.7 - 16.7	3.5 - 7.7
# of Samples	75	10	24	23	18
Segment II					
Mean ± s.d.	4.5 ± 1.5	3.8 ± 0.7	4.5 ± 0.9	5.2 ± 2.3	3.8 ± 0.9
Range	2.4 - 12.3	3.1 - 5.6	3.0 - 6.6	2.4 - 12.3	2.5 - 6.4
# of Samples	140	13	55	41	31
Segment III					
Mean ± s.d.	5.0 ± 1.6	4.7 ± 1.0	4.3 ± 1.0	6.2 ± 2.1	4.4 ± 1.0
Range	3.0 - 10.6	3.3 - 6.1	3.0 - 6.1	3.9 - 10.6	3.6 - 5.9
# of Samples	45	5	19	14	7
Segment IV					
Mean ± s.d.	3.3 ± 1.1	2.7 ± 0.6	3.0 ± 0.7	4.2 ± 1.4	2.9 ± 0.4
Range	1.8 - 7.9	2.2 - 3.8	1.8 - 4.8	2.5 - 7.9	2.1 - 4.2
# of Samples	130	6	56	39	29
Segment V					
Mean ± s.d.	3.5 ± 1.1	2.8 ± 0.3	3.0 ± 0.7	4.4 ± 1.2	3.5 ± 0.9
Range	1.9 - 7.1	2.5 - 3.2	1.9 - 4.7	2.6 - 7.1	2.6 - 6.2
# of Samples	92	5	39	27	21
Total Bay					
Mean ± s.d.	4.3 ± 1.9	3.9 ± 1.1	4.0 ± 1.5	5.2 ± 2.6	3.7 ± 1.0
Range	1.8 - 16.7	2.2 - 6.1	1.8 - 9.9	2.4 - 16.7	2.1 - 7.7
# of Samples	482	39	193	144	106

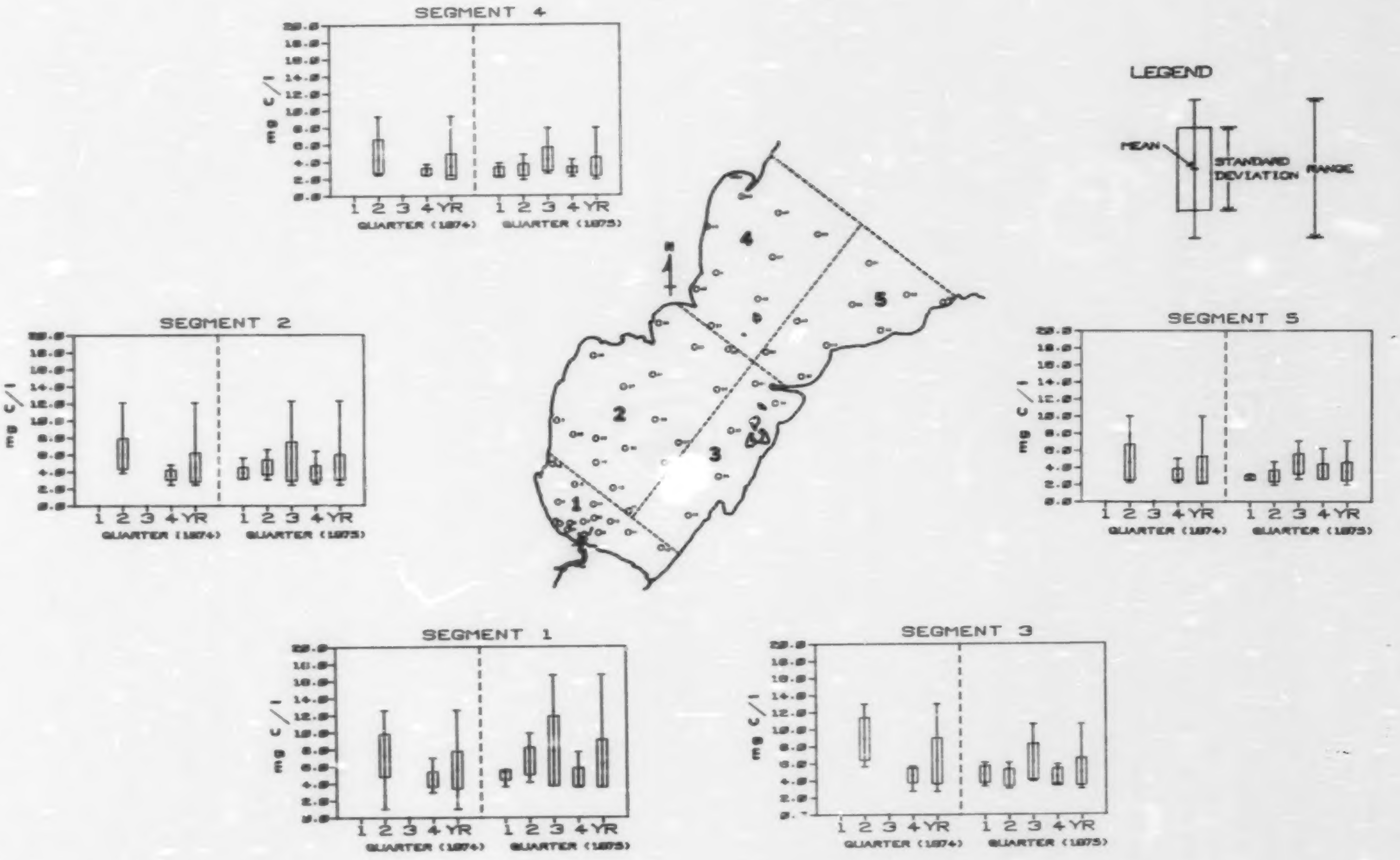


Figure 30. Data summary of filtered organic carbon (mg C/ℓ).

tion 50 (segment 4). The 1974-75 mean value of 202.8 mg/ℓ at station 3 was closest to the total bay mean of 206.9 mg/ℓ.

Mean values by segment ranged from 85.4 mg/ℓ (segment 2, 1974) to 262.3 mg/ℓ (segment 1, 1975). The greatest annual range, 74 mg/ℓ - 330 mg/ℓ, occurred in segment 4 (1975). In 1974 the mean value of 167.2 mg/ℓ in segment 1 was closest to the total bay mean of 127.4 mg/ℓ. In 1975 the mean of 189.3 mg/ℓ in segment 2 was closest to the bay mean of 182.5 mg/ℓ.

Quarterly and annual summaries of all u. tot. solids data compiled for each segment and the total bay are shown in Table 21 and Figure 31.

Silicate-silicon, filtered reactive (f. reac. SiO_2-Si)

The highest mean filtered reactive silicate-silicon level of 3.99 mg SiO_2/ℓ during 1974-75 was recorded at station 54 (river). The lowest of 0.27 mg SiO_2/ℓ was at station 60 (segment 2). The 1974-75 mean value of 1.08 mg SiO_2/ℓ at station 58 was closest to the total bay mean of 1.06 mg SiO_2/ℓ.

Mean values by segment ranged from 0.44 mg SiO_2/ℓ (segment 3, 1975) to 1.08 mg SiO_2/ℓ (segment 4, 1974). The greatest annual range, 0.08 mg SiO_2/ℓ - 7.49 mg SiO_2/ℓ, occurred in segment 1 (1975). In 1974 the mean value of 0.98 mg SiO_2/ℓ in segment 5 was closest to the total bay mean of 0.99 mg SiO_2/ℓ. In 1975 the mean of 0.54 mg SiO_2/ℓ in segment 5 was closest to the bay mean of 0.55 mg SiO_2/ℓ.

Quarterly and annual summaries of all f. reac. silicate-silicon data compiled for each segment and the total bay are shown in Table 22 and Figure 32.

Ammonia-nitrogen, filtered total (f. tot. NH_3-N)

The highest mean filtered total ammonia-nitrogen level of 0.354 mg N/ℓ during 1974-75 was recorded at station 1 (river). The lowest of 0.010 mg N/ℓ was at station 60 (segment 2). The 1974-75 mean value of 0.052 mg N/ℓ at station 15 was closest to the total bay mean of 0.061 mg N/ℓ.

Mean values by segment ranged from 0.014 mg N/ℓ (segment 4, 1975) to 0.059 mg N/ℓ (segment 1, 1974). The greatest annual range, 0.001 mg N/ℓ - 2.14 mg N/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 0.039 mg N/ℓ in segment 2 was closest to the total bay mean of 0.037 mg N/ℓ. In 1975 the mean of 0.015 mg N/ℓ in segments 2, 3, 5 was closest to the bay mean of 0.018 mg N/ℓ.

Quarterly and annual summaries of all f. tot. ammonia-N data compiled for each segment and the total bay are shown in Table 23 and Figure 33.

Nitrate + nitrite-nitrogen, filtered (f. NO_3 + NO_2-N)

The highest mean filtered nitrate + nitrite-N level of 0.816 mg N/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 0.123 mg

TABLE 21. DATA SUMMARY OF UNFILTERED TOTAL SOLIDS (mg/ℓ) PLOTTED IN FIGURE 31

1974

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-A)	4th (S-D)
Segment I					
Mean ± s.d.	167.2 ± 90.6	-	-	-	167.2 ± 90.6
Range	80 - 310	-	-	-	80 - 310
# of Samples	5	-	-	-	5
Segment II					
Mean ± s.d.	85.4 ± 17.4	-	-	-	85.4 ± 17.4
Range	66 - 114	-	-	-	66 - 114
# of Samples	7	-	-	-	7
Segment III					
Mean ± s.d.	175.0 ± 4.2	-	-	-	175.0 ± 4.2
Range	172 - 178	-	-	-	172 - 178
# of Samples	2	-	-	-	2
Segment IV					
Mean ± s.d.	-	-	-	-	-
Range	-	-	-	-	-
# of Samples	-	-	-	-	-
Segment V					
Mean ± s.d.	-	-	-	-	-
Range	-	-	-	-	-
# of Samples	-	-	-	-	-
Total Bay					
Mean ± s.d.	127.4 ± 67.6	-	-	-	127.4 ± 67.6
Range	66 - 310	-	-	-	66 - 310
# of Samples	14	-	-	-	14

1975

Segment I					
Mean ± s.d.	262.3 ± 56.2	-	289.3 ± 42.9	241.5 ± 59.3	274.0 ± 51.0
Range	172 - 376	-	220 - 346	172 - 376	236 - 332
# of Samples	30	-	11	16	3
Segment II					
Mean ± s.d.	189.3 ± 29.2	-	195.6 ± 34.2	186.2 ± 22.4	151.0 ± 4.2
Range	126 - 254	-	126 - 254	158 - 242	148 - 154
# of Samples	54	-	25	27	2
Segment III					
Mean ± s.d.	191.4 ± 32.5	-	194.0 ± 44.3	194.5 ± 21.5	187.3 ± 22.5
Range	120 - 270	-	120 - 270	178 - 244	168 - 212
# of Samples	25	-	11	11	3
Segment IV					
Mean ± s.d.	146.3 ± 37.8	-	146.8 ± 52.2	146.9 ± 22.8	120
Range	74 - 330	-	74 - 330	108 - 182	120
# of Samples	49	-	21	27	1
Segment V					
Mean ± s.d.	151.3 ± 29.2	-	132.8 ± 21.9	160.6 ± 28.3	-
Range	104 - 212	-	104 - 172	104 - 212	-
# of Samples	36	-	12	24	-
Total Bay					
Mean ± s.d.	182.5 ± 53.2	-	185.0 ± 62.0	179.0 ± 44.1	200.7 ± 65.5
Range	74 - 376	-	74 - 346	104 - 376	120 - 332
# of Samples	194	-	80	105	9

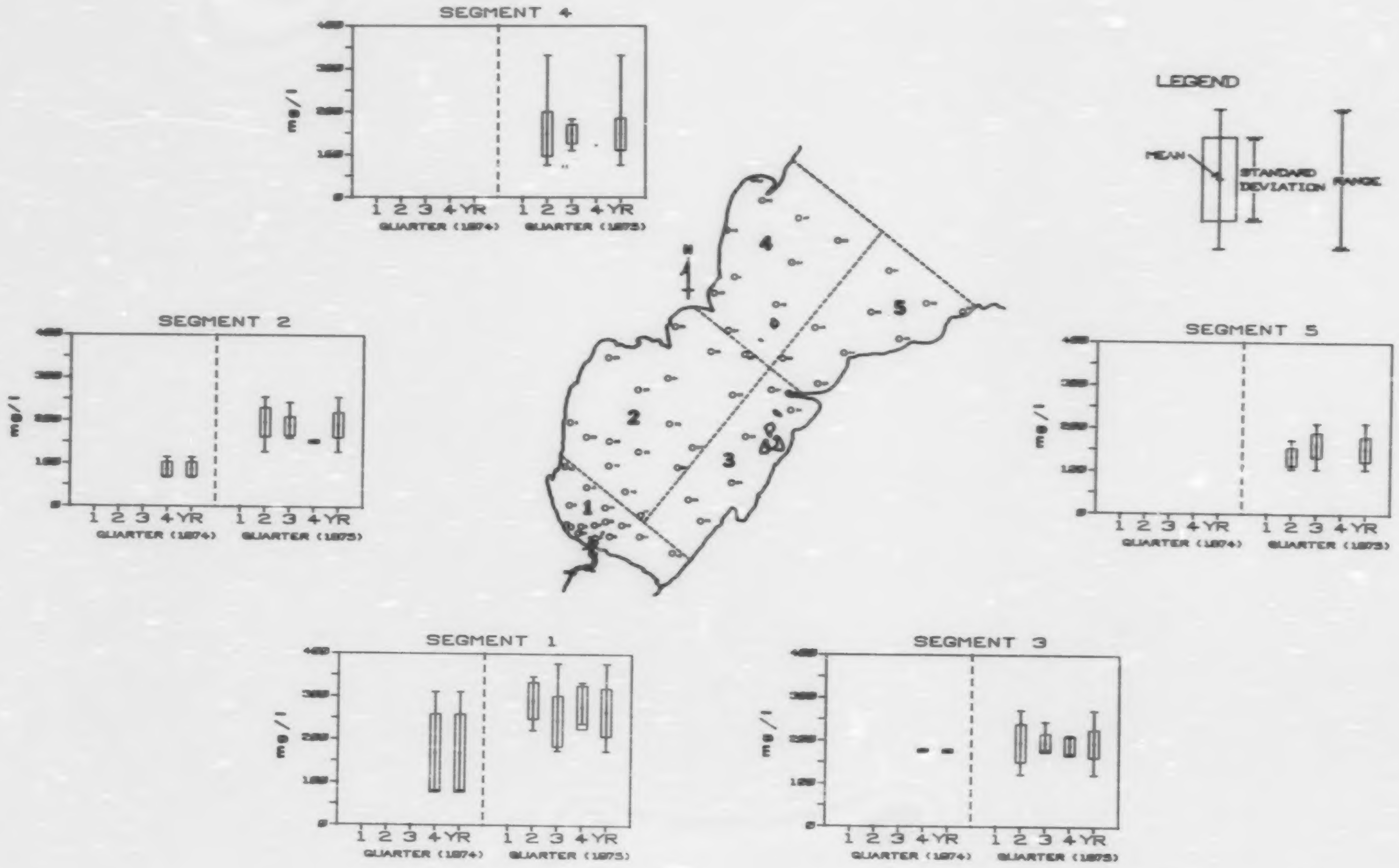


Figure 31. Data summary of unfiltered total solids (mg/ℓ).

TABLE 22. DATA SUMMARY OF FILTERED REACTIVE SILICATE-SILICON ($mg\ SiO_2/\ell$), PLOTTED IN FIGURE 32

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	.88 ± .70	1.96 ± 1.74	.65 ± .70	.95 ± .50	1.15 ± .51
Range	.07 - 3.94	.30 - 3.94	.07 - 3.0	.32 - 2.16	.24 - 1.94
# of Samples	200	6	89	69	36
Segment II					
Mean ± s.d.	1.05 ± .65	1.38 ± .64	.71 ± .58	1.25 ± .54	1.44 ± .65
Range	.05 - 3.69	.92 - 1.83	.05 - 3.69	.50 - 3.21	.13 - 2.91
# of Samples	275	2	117	109	47
Segment III					
Mean ± s.d.	.72 ± .39	.54 ± .28	.57 ± .39	.89 ± .37	.73 ± .33
Range	.05 - 1.87	.10 - .85	.05 - 1.87	.45 - 1.72	.08 - 1.29
# of Samples	68	5	26	26	11
Segment IV					
Mean ± s.d.	1.08 ± .33	1.06 ± .06	1.03 ± .35	1.03 ± .29	1.27 ± .33
Range	.070 - 2.03	1.01 - 1.13	.07 - 1.94	.64 - 1.98	.75 - 2.03
# of Samples	256	5	109	94	48
Segment V					
Mean ± s.d.	.98 ± .42	.89 ± .10	.92 ± .57	1.03 ± .30	.97 ± .20
Range	.040 - 3.17	.81 - 1.03	.04 - 3.17	.52 - 2.10	.53 - 1.29
# of Samples	209	4	86	83	36
Total Bay					
Mean ± s.d.	.99 ± .55	1.14 ± .03	.62 ± .57	1.07 ± .44	1.20 ± .50
Range	.05 - 3.94	.10 - 3.94	.05 - 3.69	.32 - 3.21	.08 - 2.91
# of Samples	1,011	23	429	381	178

1975

Segment 1					
Mean ± s.d.	.69 ± 1.32	.74 ± .44	.49 ± .68	.99 ± 2.00	.41 ± .85
Range	.08 - 7.49	.09 - 1.33	.08 - 2.60	.08 - 7.49	.08 - 3.33
# of Samples	73	10	23	26	14
Segment II					
Mean ± s.d.	.47 ± .41	.33 ± .27	.44 ± .30	.61 ± .55	.30 ± .26
Range	.08 - 3.67	.09 - 1.09	.08 - 1.43	.08 - 3.67	.08 - 1.05
# of Samples	214	12	80	75	47
Segment III					
Mean ± s.d.	.44 ± .39	.27 ± .16	.38 ± .26	.67 ± .51	.19 ± .18
Range	.08 - 1.68	.09 - .45	.08 - 1.10	.16 - 1.68	.08 - .49
# of Samples	56	5	23	20	8
Segment IV					
Mean ± s.d.	.64 ± .55	1.33 ± .25	1.02 ± .55	.37 ± .36	.34 ± .35
Range	.08 - 2.29	.89 - 1.55	.09 - 2.29	.08 - 1.56	.08 - 1.81
# of Samples	238	7	90	83	58
Segment V					
Mean ± s.d.	.54 ± .51	1.16 ± .38	.81 ± .51	.32 ± .36	.34 ± .44
Range	.08 - 2.24	.48 - 1.50	.08 - 1.62	.08 - 1.50	.08 - 2.24
# of Samples	189	6	72	65	46
Total Bay					
Mean ± s.d.	.55 ± .63	.73 ± .52	.70 ± .54	.51 ± .79	.33 ± .42
Range	.08 - 7.49	.09 - 1.55	.08 - 2.60	.08 - 7.49	.08 - 3.33
# of Samples	770	40	288	269	173

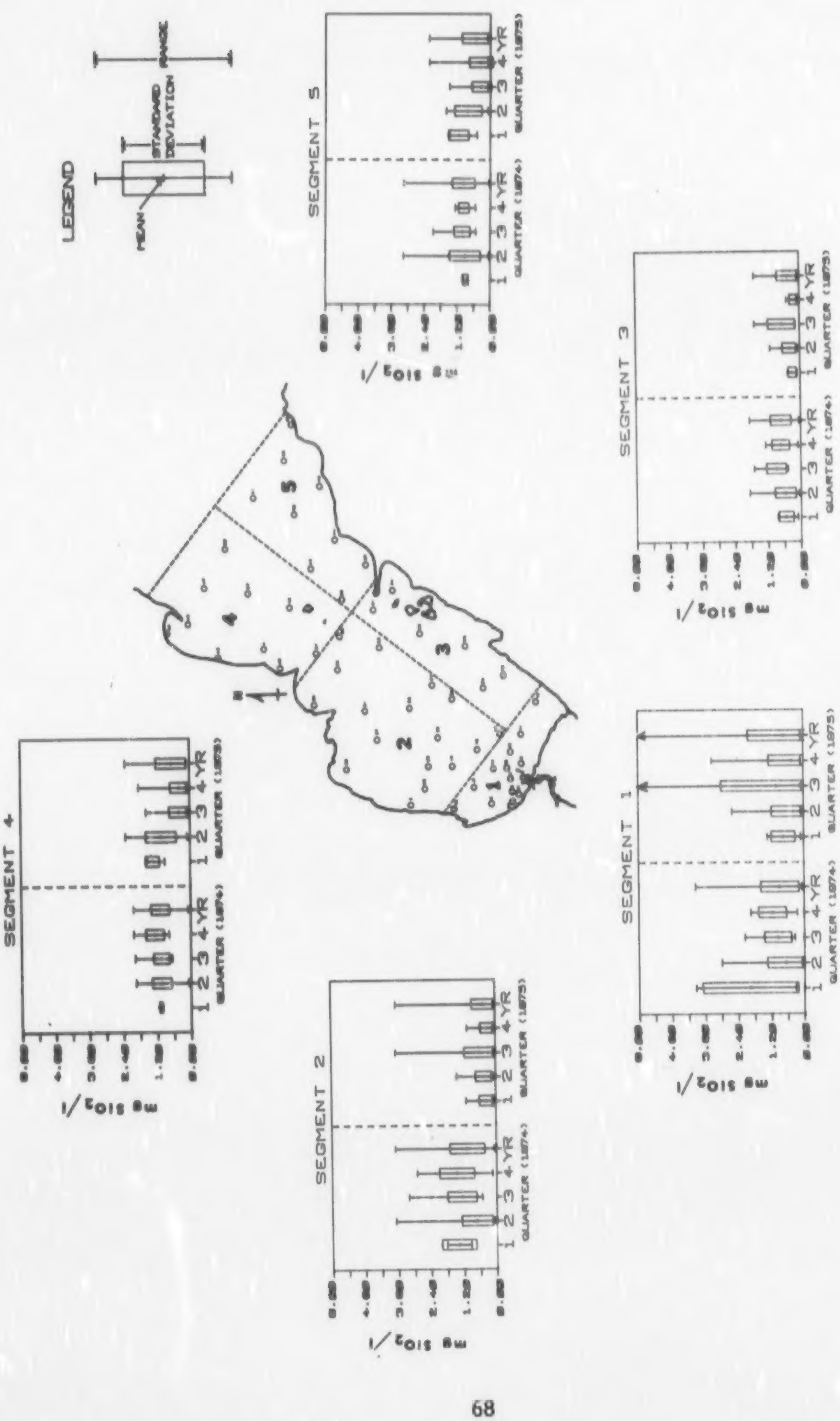


Figure 32. Data summary of filtered reactive silicate-silicon (mg SiO$_2$/ℓ).

TABLE 23. DATA SUMMARY OF FILTERED TOTAL AMMONIA-NITROGEN (mg N/ℓ), PLOTTED IN FIGURE 33

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	.059 ± .157	.409 ± .850	.041 ± .044	.046 ± .033	.078 ± .114
Range	.001-2.140	.001 - 2.140	.005 - .150	.005 - .144	.010 - .620
# of Samples	208	6	97	69	36
Segment II					
Mean ± s.d.	.039 ± .030	.076 ± .034	.032 ± .027	.050 ± .034	.032 ± .018
Range	.005 - .144	.052 - .100	.005 - .144	.008 - .144	.016 - .127
# of Samples	277	2	120	108	47
Segment III					
Mean ± s.d.	.032 ± .037	.016 ± .008	.023 ± .018	.047 ± .053	.024 ± .006
Range	.005 - .239	.007 - .029	.005 - .073	.008 - .239	.016 - .035
# of Samples	65	5	23	26	11
Segment IV					
Mean ± s.d.	.024 ± .016	.011 ± .004	.015 ± .010	.033 ± .019	.028 ± .010
Range	.005 - .128	.007 - .015	.005 - .061	.005 - .128	.017 - .084
# of Samples	254	5	107	94	48
Segment V					
Mean ± s.d.	.026 ± .020	.012 ± .004	.024 ± .026	.031 ± .016	.023 ± .008
Range	.005 - .135	.009 - .018	.005 - .135	.005 - .086	.010 - .036
# of Samples	208	4	85	83	36
Total Bay					
Mean ± s.d.	.037 ± .076	.122 ± .442	.028 ± .030	.041 ± .030	.038 ± .056
Range	.001 - 2.14	.001 - 2.14	.005 - .150	.005 - .239	.010 -.620
# of Samples	1,015	22	434	380	178

1975

Segment 1					
Mean ± s.d.	.032 ± .036	.041 ± .027	.025 ± .033	.153	.022 ± .029
Range	.003 - .153	.011 - .108	.007 - .117	.153	.003 - .095
# of Samples	34	10	10	1	13
Segment II					
Mean ± s.d.	.015 ± .015	.040 ± .026	.014 ± .006	.006 ± .007	.008 ± .004
Range	.003 - .115	.007 - .115	.007 - .035	.003 - .023	.003 - .022
# of Samples	79	12	32	7	28
Segment III					
Mean ± s.d.	.015 ± .011	.032 ± .006	.011 ± .005	-	.009 ± .003
Range	.003 - .041	.024 - .041	.007 - .021	-	.003 - .012
# of Samples	23	5	10	-	8
Segment IV					
Mean ± s.d.	.014 ± .011	.025 ± .010	.015 ± .012	-	.010 ± .006
Range	.003 - .048	.007 - .036	.007 - .048	-	.003 - .031
# of Samples	61	7	28	-	26
Segment V					
Mean ± s.d.	.015 ± .009	.029 ± .005	.011 ± .007	-	.016 ± .009
Range	.006 - .038	.025 - .037	.007 - .032	-	.006 - .038
# of Samples	56	6	19	-	31
Total Bay					
Mean ± s.d.	.018 ± .020	.037 ± .025	.014 ± .013	.035 ± .059	.012 ± .013
Range	.003 - .153	.007 - .115	.007 - .117	.003 - .153	.003 - .095
# of Samples	253	40	99	8	106

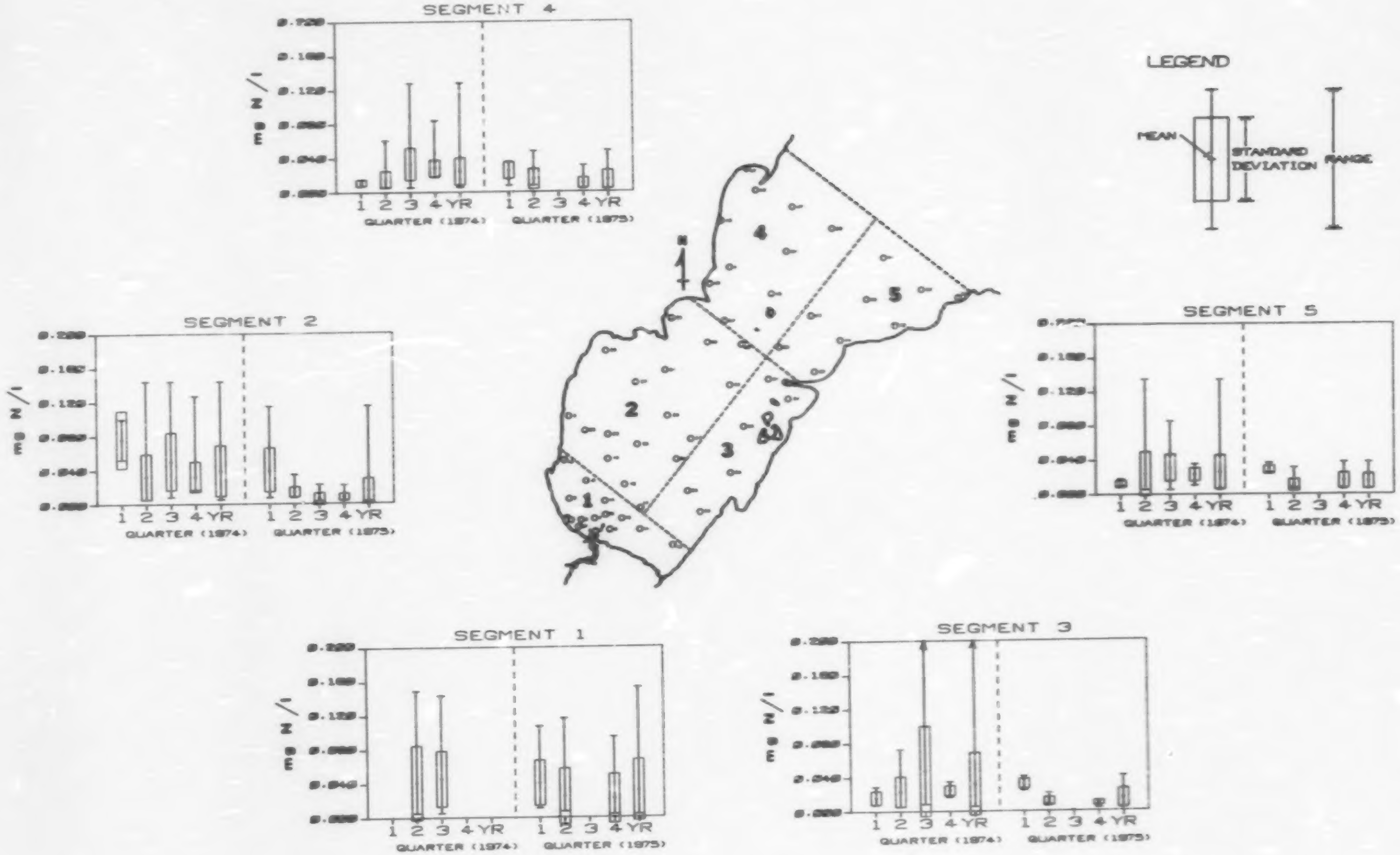


Figure 33. Data summary of filtered total ammonia-nitrogen (mg N/ℓ).

N/ℓ was at station 30 (segment 2). The 1974-75 mean value of 0.316 mg N/ℓ at station 59 was closest to the total bay mean of 0.312 mg N/ℓ.

Mean values by segment ranged from 0.200 mg N/ℓ (segment 2, 1975) to 0.498 mg N/ℓ (segment 3, 1974). The greatest annual range, 0.05 mg N/ℓ - 4.2 mg N/ℓ, occurred in segment 3 (1974). In 1974 the mean value of 0.277 mg N/ℓ in segment 2 was closest to the total bay mean of 0.295 mg N/ℓ. In 1975 the mean of 0.215 mg N/ℓ in segment 5 was closest to the bay mean of 0.225 mg N/ℓ.

Quarterly and annual summaries of all f. nitrate + nitrite-N data compiled for each segment and the total bay are shown in Table 24 and Figure 34.

Nitrogen, unfiltered Kjeldahl (u. Kjel. N)

The highest mean unfiltered Kjeldahl nitrogen level of 1.293 mg N/ℓ during 1974-75 was recorded at station 54 (river). The lowest of 0.155 mg N/ℓ was at station 50 (segment 4). The 1974-75 mean value of 0.425 mg N/ℓ at station 15 was closest to the total bay mean of 0.426 mg N/ℓ.

Mean values by segment ranged from 0.201 mg N/ℓ (segment 4, 1974) to 0.64 mg N/ℓ (segment 1, 1975). The greatest annual range, 0.22 mg N/ℓ - 1.97 mg N/ℓ, occurred in segment 1 (1975). In 1974 the mean value of 0.338 mg N/ℓ in segment 2 was closest to the total bay mean of 0.326 mg N/ℓ. In 1975 the mean of 0.36 mg N/ℓ in segment 2 was closest to the bay mean of 0.33 mg N/ℓ.

Results showing the variation by cruise (at two depths) of u. Kjel. nitrogen at selected stations are given in Table 25 and Figure 35. Quarterly and annual summaries of all u. Kjel. N data compiled for each segment and the total bay are shown in Table 26 and Figure 36.

Twice-weekly u. Kjel. N data from four intake plants (plotted in Figure 37) are compared in Table 27 to regular cruise data for the same sites.

Nitrogen, total (tot. N, computed as u. Kjel. N + f. NO_3 + NO_2-N)

The highest mean total nitrogen level of 2.121 mg N/ℓ during 1974-75 was recorded at station 54 (river). The lowest of 0.383 mg N/ℓ was at station 50 (segment 4). The 1974-75 mean value of 0.719 mg N/ℓ at station 10 was closest to the total bay mean of 0.706 mg N/ℓ.

Mean values by segment ranged from 0.418 mg N/ℓ (segment 4, 1975) to 0.968 mg N/ℓ (segment 1, 1975). The greatest annual range, 0.31 mg N/ℓ - 2.87 mg N/ℓ, occurred in segment 3 (1975). In 1974 the mean value of 0.474 mg N/ℓ in segment 5 was closest to the total bay mean of 0.544 mg N/ℓ. In 1975 the mean of 0.574 mg N/ℓ in segment 2 was closest to the bay mean of 0.557 mg N/ℓ.

Results showing the variation by cruise (at two depths) of total nitrogen at selected stations are given in Table 28 and Figure 38. Quarterly and an-

TABLE 24. DATA SUMMARY OF FILTERED NITRATE + NITRITE-NITROGEN (mg N/ℓ), PLOTTED IN FIGURE 34

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment I					
Mean ± s.d.	.348 ± .437	1.824 ± 1.239	.528 ± .301	.090 ± .045	0.111 ± .083
Range	.050-3.250	.282 - 3.250	.174 - 1.600	.050 - .268	.050 - .318
# of Samples	208	6	97	69	36
Segment II					
Mean ± s.d.	.277 ± .282	1.105 ± .018	.485 ± .296	.110 + .054	.094 ± .056
Range	.050-1.600	1.092 - 1.117	.050 - 1.600	.050 - .361	.050 - .258
# of Samples	279	2	121	109	47
Segment III					
Mean ± s.d.	.498 ± .680	1.331 ± 1.617	.887 ± .532	.084 ± .020	.111 ± .061
Range	.050-4.199	.340 - 4.199	.050 - 1.684	.050 - .116	.050 - .244
# of Samples	70	5	28	26	11
Segment IV					
Mean ± s.d.	.232 ± .070	.314 ± .068	.288 ± .049	.186 ± .047	.180 ± .038
Range	.060 - .490	.259 - .431	.164 - .490	.072 - .298	.060 - .335
# of Samples	261	5	114	94	48
Segment V					
Mean ± s.d.	.249 ± .164	.321 ± .037	.379 ± .195	.170 ± .056	.149 ± .050
Range	.050-1.326	.295 - .376	.074 - 1.326	.066 - .311	.050 - .270
# of Samples	198	4	75	83	36
Total Bay					
Mean ± s.d.	.295 ± .344	1.168 ± 1.289	.450 ± .301	.137 ± .064	.133 ± .069
Range	.050-4.199	.259 - 4.199	.050 - 1.684	.050 - .361	.05 - .318
# of Samples	1,019	21	437	381	178

1975

Segment I					
Mean ± s.d.	.336 ± .379	.553 ± .133	.503 ± .434	.161 ± .265	.231 ± .412
Range	.050 - 1.582	.246 - .740	.076 - 1.582	.050 - .970	.050 - 1.291
# of Samples	73	10	23	26	14
Segment II					
Mean ± s.d.	.200 ± .163	.345 ± .116	.332 ± .165	.097 ± .060	.088 ± .043
Range	.050 - .798	.195 - .644	.050 - .798	.050 - .335	.050 - .184
# of Samples	214	12	80	75	47
Segment III					
Mean ± s.d.	.299 ± .400	.827 ± .665	.471 ± .393	.051 ± .006	.095 ± .050
Range	.050 - 1.963	.286 - 1.963	.050 - 1.548	.050 - .075	.050 - .159
# of Samples	56	5	23	20	8
Segment IV					
Mean ± s.d.	.209 ± .068	.287 ± .018	.249 ± .069	.172 ± .053	.189 ± .045
Range	.050 - .678	.263 - .317	.091 - .678	.050 - .274	.050 - .295
# of Samples	238	7	90	83	58
Segment V					
Mean ± s.d.	.215 ± .187	.619 ± .804	.294 ± .105	.140 ± .070	.144 ± .073
Range	.050 - 2.261	.279 - 2.261	.182 - .805	.050 - .294	.050 - .316
# of Samples	189	6	72	65	46
Total Bay					
Mean ± s.d.	.225 ± .214	.485 ± .402	.321 ± .215	.135 ± .119	.149 ± .140
Range	.050 - 2.261	.195 - 2.261	.050 - 1.582	.050 - .970	.050 - 1.291
# of Samples	770	40	288	269	175

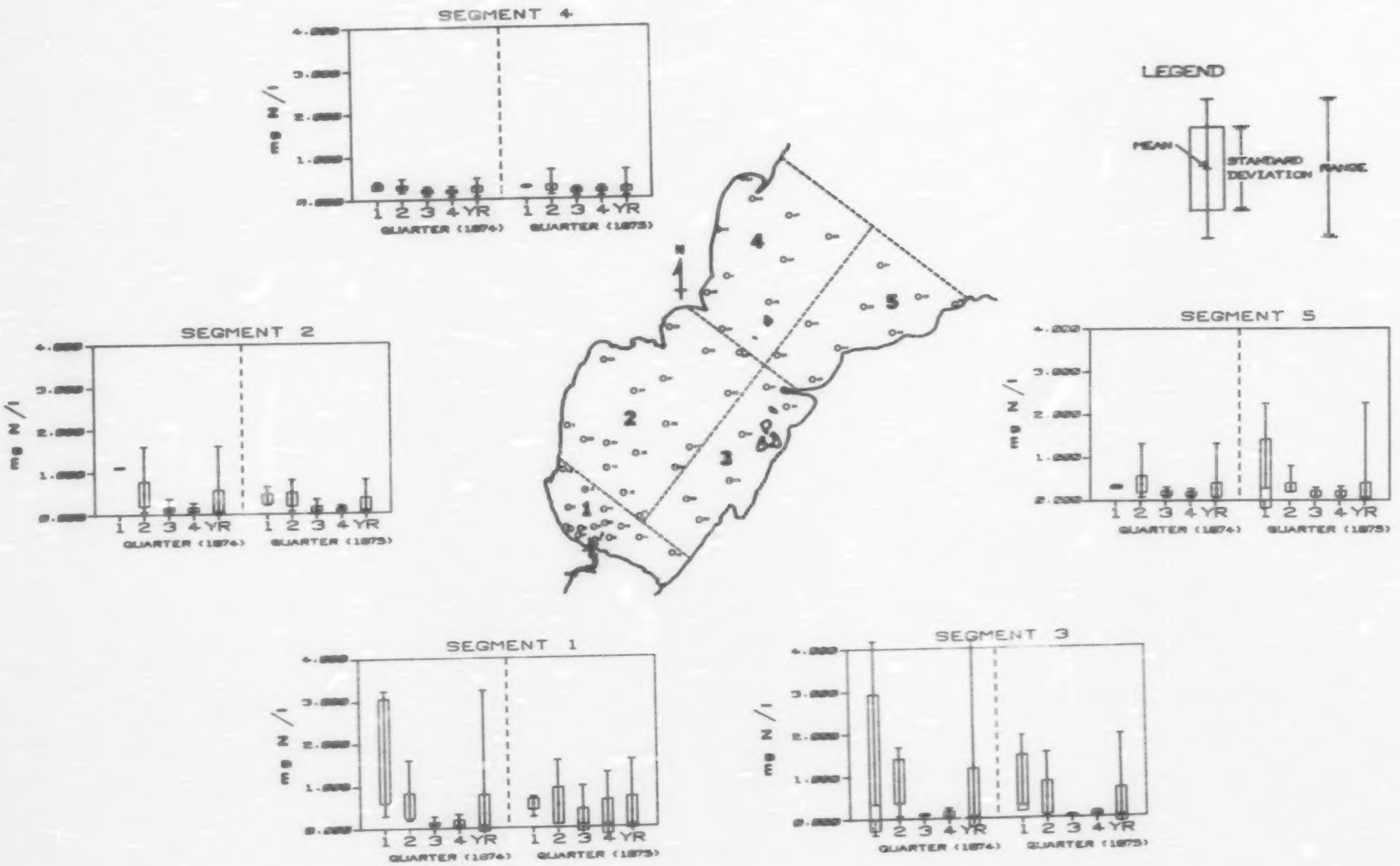


Figure 34. Data summary of filtered nitrate + nitrite-nitrogen (mg N/ℓ).

TABLE 25. UNFILTERED KJELDAHL NITROGEN (mg N/ℓ) AT SELECTED STATIONS, PLOTTED IN FIGURE 35

Station Number	Location	Depth In Meters	Mean* (Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	1.290 (0.730-2.350)	0.460	74-6-3	75-10-27
		8	1.250 (0.680-2.150)	0.400	74-4-29	75-10-27
8	Segment I	1	0.630 (0.190-1.240)	0.310	74-6-20	74-7-27
		3	0.540 (0.210-1.300)	0.280	74-6-20	74-7-27
35	Segment II	1	0.280 (0.080-0.630)	0.110	75-7-29	75-9-3
		10	0.250 (0.090-0.690)	0.130	75-7-29	75-4-30
34	Segment III	1	0.620 (0.280-1.030)	0.260	75-2-19	74-7-26
		3	0.720 (0.430-1.120)	0.230	75-5-22	74-7-26
49	Segment IV	1	0.180 (0.080-0.360)	0.080	75-10-10	75-6-26
		20	0.150 (0.050-0.410)	0.080	75-5-21	74-10-7
51	Segment V	1	0.170 (0.050-0.340)	0.080	75-5-21	75-6-6
		28	0.130 (0.060-0.250)	0.060	74-9-19	74-7-26

*Mid-winter data included for 1 m depth only.

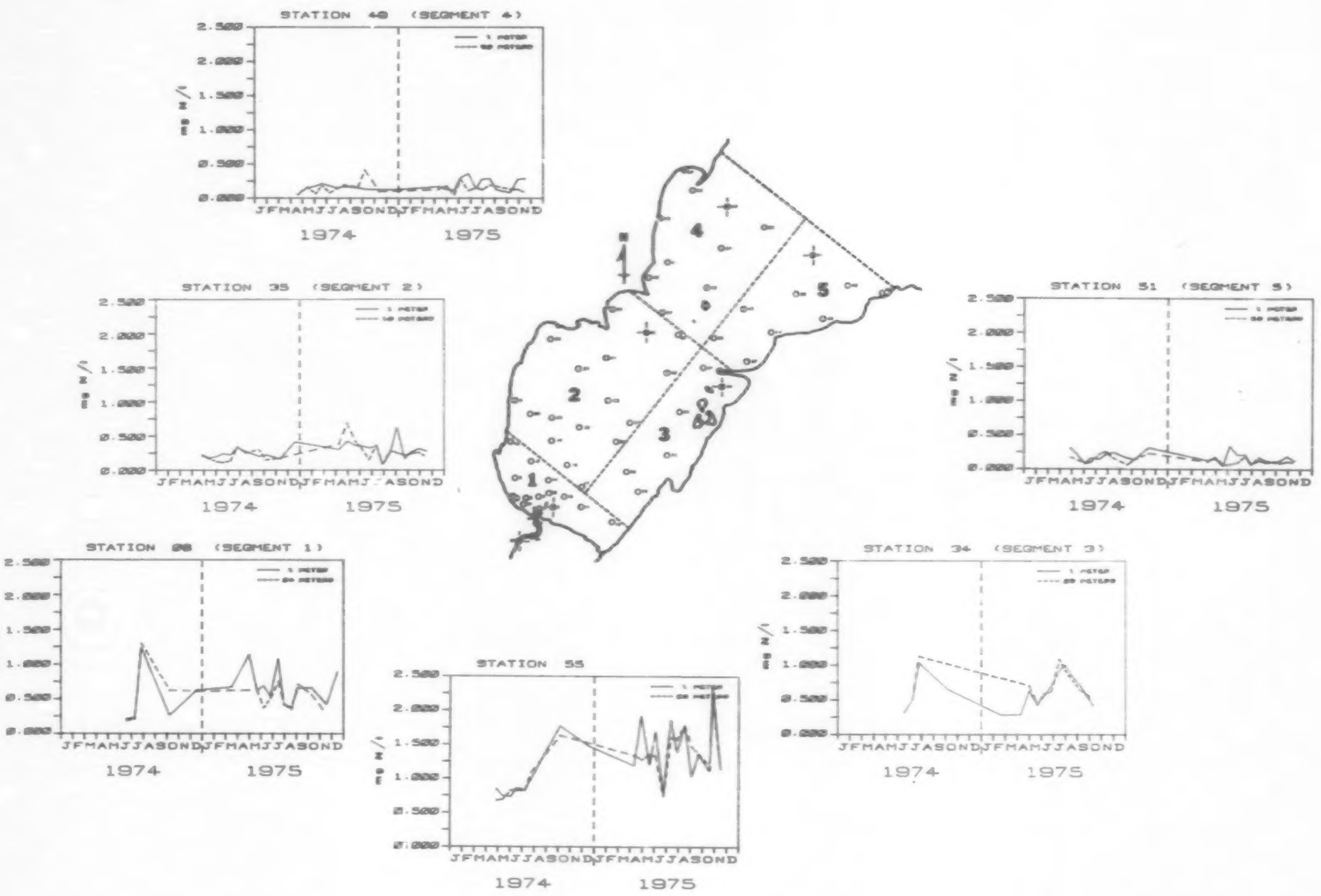


Figure 35. Unfiltered Kjeldahl nitrogen (mg N/ℓ) at selected stations (-|-).

TABLE 26. DATA SUMMARY OF UNFILTERED KJELDAHL NITROGEN (mg N/ℓ), PLOTTED IN FIGURE 36

1974

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-A)	4th (S-D)
Segment 1					
Mean ± s.d.	.506 ± .308	-	.314 ± .114	.627 ± .408	.536 ± .191
Range	.120-1.380	-	.160 - .620	.120 - 1.380	.260 - 1.060
# of Samples	110	-	32	42	36
Segment II					
Mean ± s.d.	.338 ± .187	-	.259 ± .120	.387 ± .168	.357 ± .247
Range	.110-1.800	-	.110 - .790	.120 - 1.190	.120 - 1.800
# of Samples	180	-	58	75	47
Segment III					
Mean ± s.d.	.494 ± .199	-	.373 ± .145	.592 ± .222	.491 ± .119
Range	.140-1.120	-	.140 - .760	.340 - 1.120	.230 - .650
# of Samples	47	-	16	20	11
Segment IV					
Mean ± s.d.	.201 ± .186	-	.142 ± .090	.229 ± .128	.223 ± .285
Range	.050-2.000	-	.050 - .530	.080 - .640	.070 - 2.00
# of Samples	157	-	48	61	48
Segment V					
Mean ± s.d.	.256 ± .138	-	.21 ± .11	.28 ± .15	.27 ± .14
Range	.060 - .750	-	.07 - .60	.06 - .75	.10 - .65
# of Samples	142	-	48	58	36
Total Bay					
Mean ± s.d.	.326 ± .233	-	.238 ± .131	.318 ± .262	.347 ± .20
Range	.050 - 2.00	-	.050 - .790	.060 - 1.380	.070 - 2.00
# of Samples	636	-	202	256	178

1975

Segment 1					
Mean ± s.d.	.64 ± .30	.45 ± .13	.78 ± .35	.65 ± .29	.50 ± .17
Range	.22 - 1.97	.22 - .67	.37 - 1.97	.35 - 1.41	.26 - .90
# of Samples	72	10	23	25	14
Segment II					
Mean ± s.d.	.36 ± .14	.29 ± .09	.40 ± .14	.36 ± .15	.34 ± .11
Range	.06 - .85	.13 - .44	.14 - .82	.06 - .85	.19 - .71
# of Samples	214	12	80	74	48
Segment III					
Mean ± s.d.	.53 ± .22	.49 ± .26	.47 ± .20	.61 ± .25	.52 ± .16
Range	.10 - 1.08	.28 -.87	.10 - .84	.26 - 1.08	.28 - .77
# of Samples	54	4	22	20	8
Segment IV					
Mean ± s.d.	.21 ± .13	.17 ± .05	.22 ± .17	.21 ± .10	.19 ± .11
Range	.05 - 1.11	.13 - .23	.05 - 1.11	.06 - .72	.050 - .600
# of Samples	240	7	90	85	58
Segment V					
Mean ± s.d.	.24 ± .14	.16 ± .02	.24 ± .15	.25 ± .14	.24 ± .13
Range	.05 - .75	.13 - .19	.05 - .75	.07 - .73	.09 - .72
# of Samples	189	6	71	66	46
Total Bay					
Mean ± s.d.	.33 ± .22	.32 ± .18	.35 ± .24	.34 ± .23	.29 ± .17
Range	.05 - 1.37	.13 - .87	.05 - 1.97	.06 - 1.41	.09 - .90
# of Samples	769	39	286	270	174

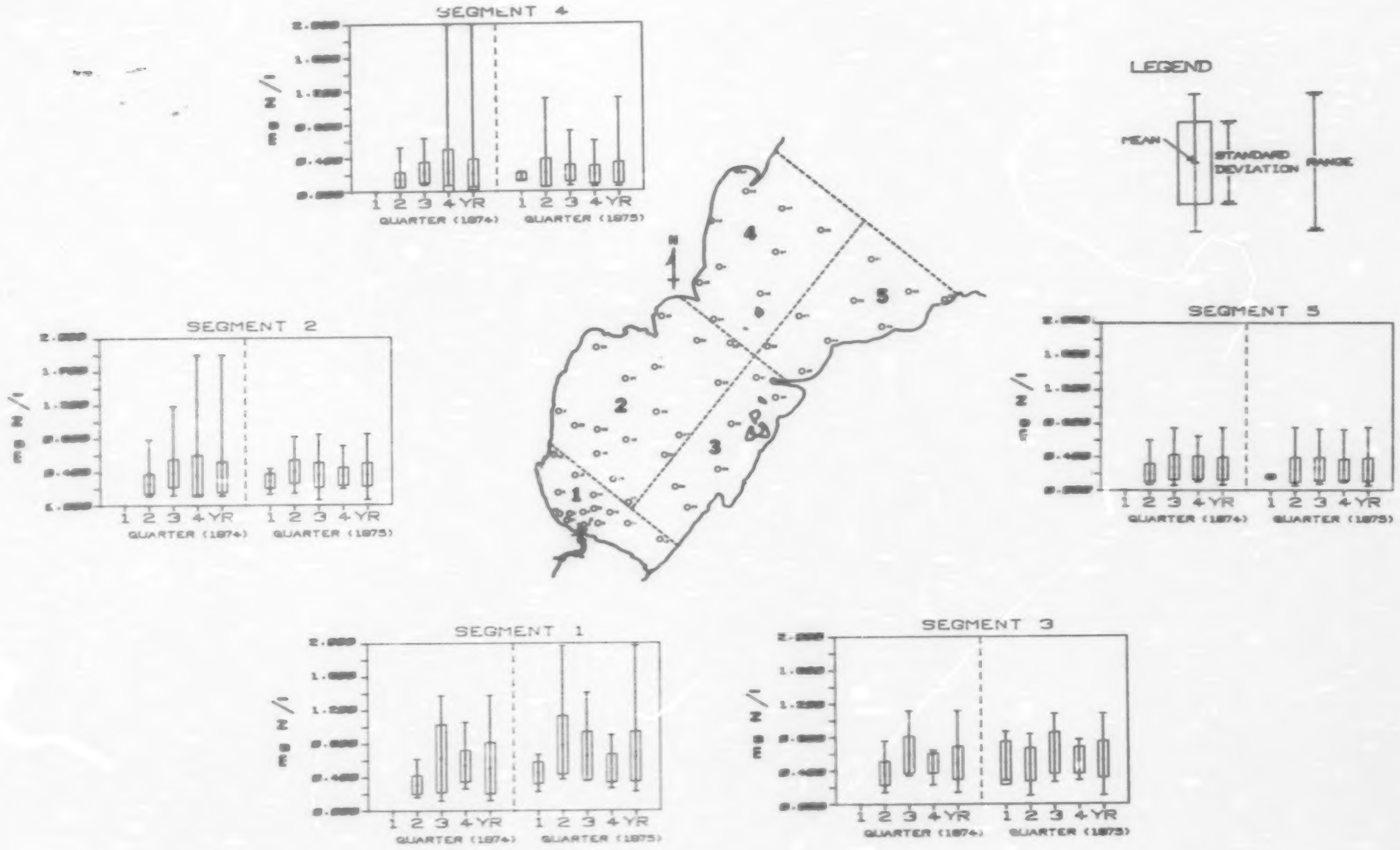


Figure 36. Data summary of unfiltered Kjeldahl nitrogen (mg N/ℓ).

TABLE 27. MEAN UNFILTERED KJELDAHL NITROGEN VALUES (mg N/ℓ) FROM CRUISE (SB) AND INTAKE PLANT (SBI) SAMPLES, PLOTTED IN FIGURE 37

		Station							
		Saginaw River		Kawkawlin		Pinconning		Whitestone Point	
	Month	SB 1	SBI 1	SB 2	SBI 2	SB 3	SBI 3	SB 4	SBI 4
1974	1	--	1.034	--	--	--	--	--	0.147
	2	--	0.843	--	--	--	--	--	0.196
	3	--	0.636	--	--	--	--	--	0.187
	4	0.760	0.598	0.430	--	--	--	--	0.154
	5	0.750	0.928	0.300	--	--	--	--	0.155
	6	0.815	0.815	0.263	--	0.360	--	0.077	0.213
	7	0.733	1.526	0.555	--	0.460	--	0.278	0.203
	8	--	1.613	0.380	--	--	--	--	0.211
	9	--	1.420	--	--	--	--	--	0.210
	10	1.355	1.203	0.470	--	0.670	--	0.105	0.195
	11	--	1.470	--	--	--	--	0.130	--
	12	2.070	1.433	0.320	0.340	--	--	--	0.225
1975	1	--	1.280	--	0.310	--	--	--	0.103
	2	1.895	1.716	--	0.155	0.220	0.303	--	0.133
	3	1.920	1.204	0.750	0.458	--	0.417	--	0.156
	4	1.390	1.094	1.120	0.538	0.640	0.608	0.150	0.264
	5	0.950	1.439	0.570	0.765	0.560	0.658	0.115	0.143
	6	0.935	1.508	0.450	0.606	0.570	0.714	0.183	0.201
	7	1.548	1.109	0.720	0.450	0.590	0.864	0.235	0.245
	8	1.225	0.776	0.470	0.398	0.460	0.578	0.295	0.166
	9	0.985	1.184	0.990	0.621	0.760	0.797	0.178	0.205
	10	1.843	1.220	0.490	0.505	0.640	0.700	0.235	0.225
	11	1.280	1.045	0.290	--	0.260	--	0.110	--
	12	--	1.241	0.640	--	--	--	--	--

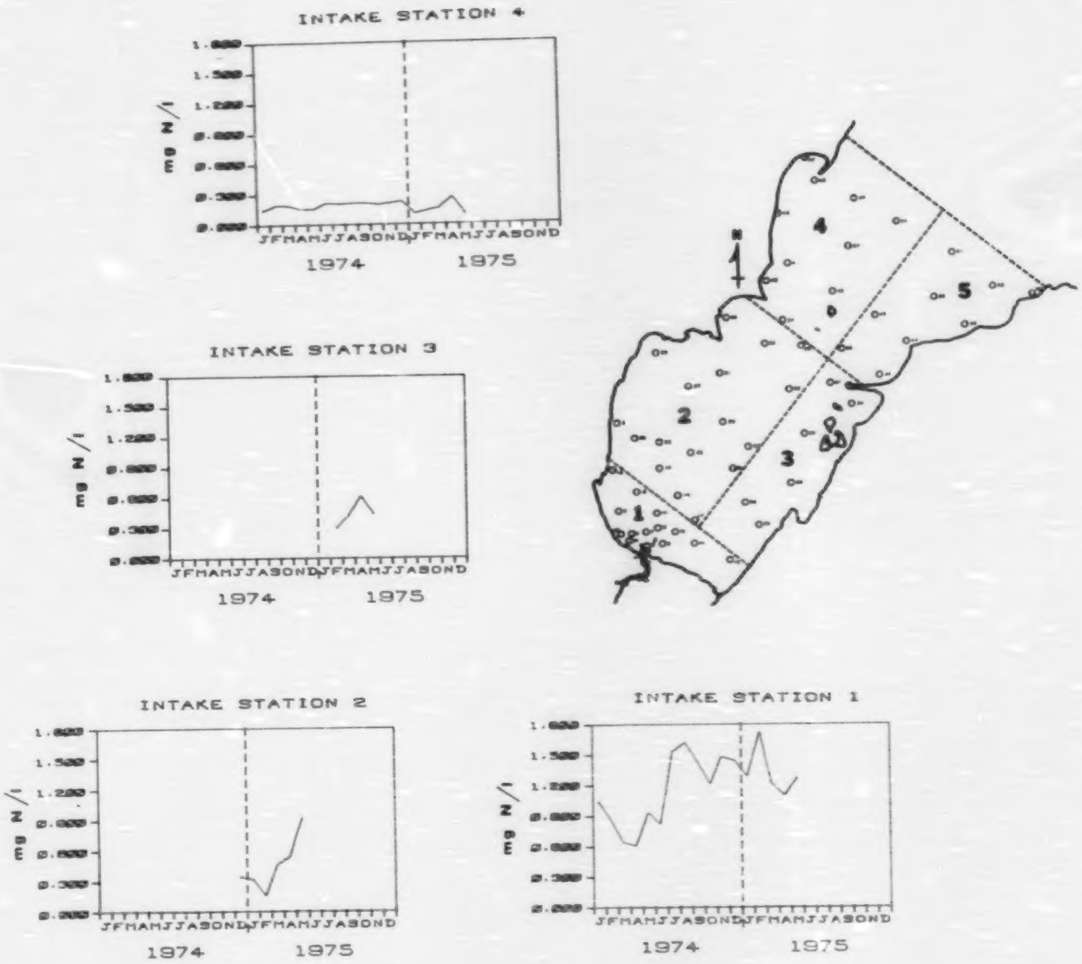


Figure 37. Unfiltered Kjeldahl nitrogen (mg N/ℓ) in twice-weekly samples from water intake plants (equivalent to stations 1, 2, 3, 4).

TABLE 28. TOTAL NITROGEN (mg N/ℓ) AT SELECTED STATIONS, PLOTTED IN FIGURE 38

Station Number	Location	Depth In Meters	Mean* (Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	2.082 (1.340-3.120)	0.511	74-06-03	75-10-27
		8	2.048 (1.290-3.040)	0.427	74-04-29	75-10-27
8	Segment I	1	0.963 (0.330-2.740)	0.630	74-06-20	74-07-27
		3	0.709 (0.340-1.350)	0.300	74-06-20	74-07-27
35	Segment II	1	0.477 (0.180-0.730)	0.144	75-07-29	75-09-03
		10	0.457 (0.250-1.090)	0.179	75-07-29	75-04-30
34	Segment III	1	0.852 (0.370-1.730)	0.328	75-02-19	74-07-26
		3	0.924 (0.550-1.900)	0.380	75-05-22	74-07-26
49	Segment IV	1	0.409 (0.280-0.600)	0.080	75-10-10	75-06-26
		20	0.413 (0.280-0.610)	0.083	75-05-21	75-10-07
51	Segment V	1	0.390 (0.220-0.600)	0.096	75-05-21	75-06-06
		28	0.399 (0.260-0.510)	0.060	74-09-19	74-07-26

*Mid-winter data included for 1 m depth only.

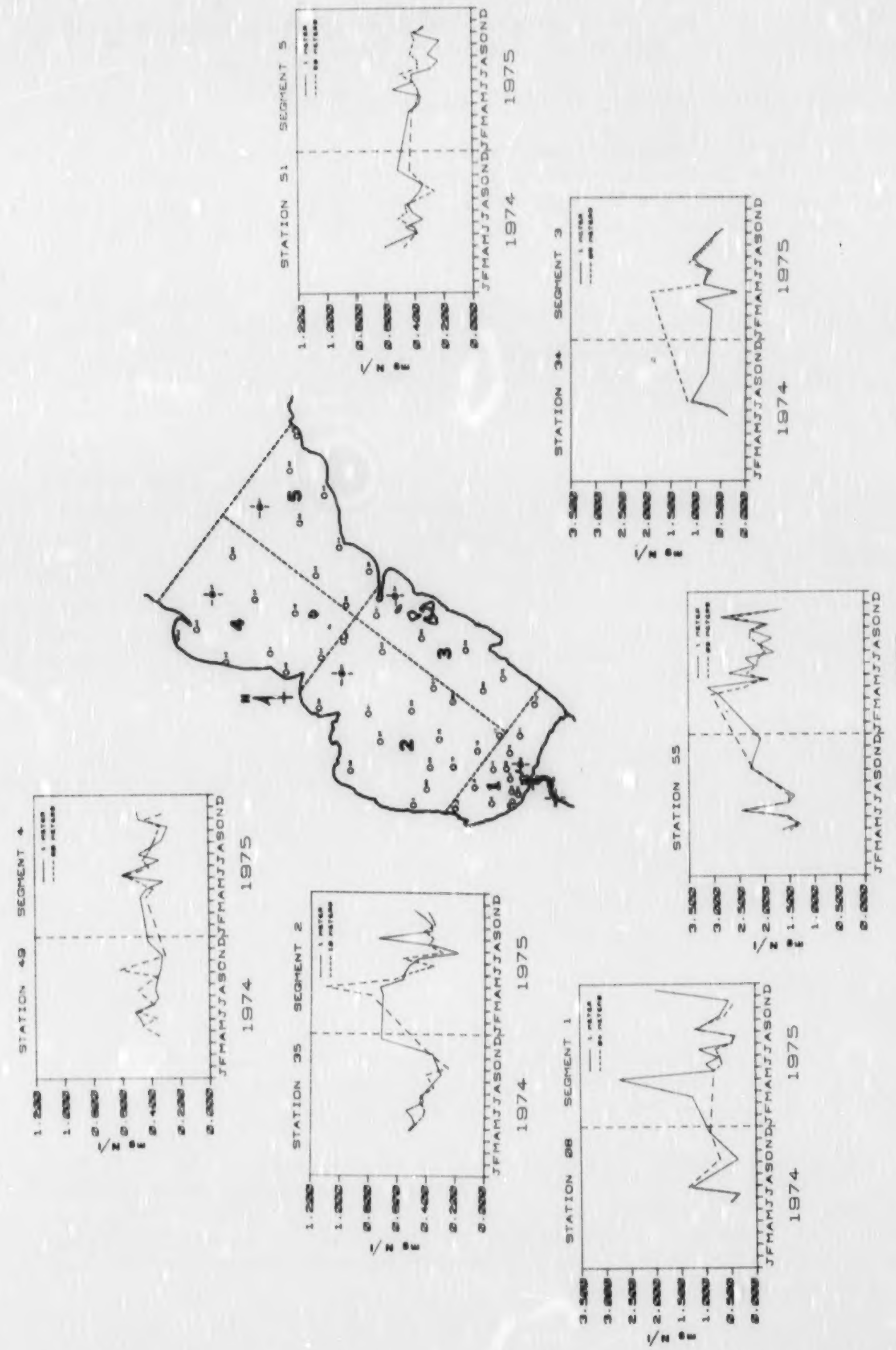


Figure 38. Total nitrogen (mg N/ℓ) at selected stations (-+-).

nual summaries of all tot. nitrogen data compiled for each segment and the total bay are shown in Table 29 and Figure 39.

Phosphate-phosphorus, filtered reactive (f. reac. PO_4-P)

The highest mean filtered reactive phosphate-phosphorus level of 0.095 mg P/ℓ during 1974-75 was recorded at station 54 (river). The lowest of 0.002 mg P/ℓ was at station 60 (segment 2). The 1974-75 mean value of 0.012 mg P/ℓ at stations 5 and 56 was closest to the total bay mean of 0.013 mg P/ℓ.

Mean values by segment ranged from 0.002 mg P/ℓ (segments 2, 3, 4, 5, 1975) to 0.011 mg P/ℓ (segment 1, 1974). The greatest annual range, 0.001 mg P/ℓ - 2.1 mg P/ℓ, occurred in segments 1, 3 (1974). In 1974 the mean value of 0.005 mg P/ℓ in segment 5 was closest to the total bay mean of 0.006 mg P/ℓ. In 1975 the mean of 0.002 mg P/ℓ in segments 2, 3, 4, 5 was identical to the bay mean.

Quarterly and annual summaries of all f. reac. PO_4-phosphorus data compiled for each segment and the total bay are shown in Table 30 and Figure 40.

Phosphorus, filtered total (f. tot. P)

The highest mean filtered total phosphorus level of 0.131 mg P/ℓ during 1974-75 was recorded at station 1 (river). The lowest of 0.003 mg P/ℓ was at station 45 (segment 4). The 1974-75 mean value of 0.021 mg P/ℓ at station 59 was identical to the total bay mean.

Mean values by segment ranged from 0.004 mg P/ℓ (segment 4, 1975 and segment 5, 1974) to 0.014 mg P/ℓ (segment 1, 1975). The greatest annual range, 0.002 mg P/ℓ - 0.125 mg P/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 0.006 mg P/ℓ in segment 2 was identical to the total bay mean. In 1975 the mean of 0.007 mg P/ℓ in segment 2 was identical to the bay mean.

Quarterly and annual summaries of all f. tot. phosphorus data compiled for each segment and the total bay are shown in Table 31 and Figure 41.

Phosphorus, unfiltered total (u. tot. P)

The highest mean unfiltered total phosphorus level of 0.267 mg P/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 0.005 mg P/ℓ was at station 51 (segment 5). The 1974-75 mean value of 0.046 mg P/ℓ at station 11 was closest to the total bay mean of 0.045 mg P/ℓ.

Mean values by segment ranged from 0.008 mg P/ℓ (segment 4, 1975) to 0.58 mg P/ℓ (segment 1, 1974 and 1975). The greatest annual range, 0.002 mg P/ℓ - 0.290 mg P/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 0.026 mg P/ℓ in segment 2 was closest to the total bay mean of 0.025 mg P/ℓ. In 1975 the mean of 0.024 mg P/ℓ in segment 2 was closest to the bay mean of 0.020 mg P/ℓ.

TABLE 29. DATA SUMMARY OF TOTAL NITROGEN (mg N/ℓ), PLOTTED IN FIGURE 39

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	.684 ± .293	-	.706 ± .273	.713 ± .352	.629 ± .23
Range	.32 - 1.43	-	.370 - 1.420	.32 - 1.43	.33 - 1.36
# of Samples	126	-	39	47	40
Segment II					
Mean ± s.d.	.535 ± .219	-	.629 ± .254	.509 ± .146	.462 ± .236
Range	.250- .185	-	.320 - 1.39	.300 - 1.29	.2 0 - 1.85
# of Samples	182	-	58	76	48
Segment III					
Mean ± s.d.	.789 ± .408	-	1.051 ± .576	.685 ± .210	.595 ± .111
Range	.37 - 2.25	-	.37 - 2.25	.440 - 1.170	.410 - .750
# of Samples	47	-	16	20	11
Segment IV					
Mean ± s.d.	.428 ± .183	-	.444 ± .103	.433 ± .106	.405 ± .290
Range	.19 - 2.20	-	.34 - .83	.28 - .74	.190 - 2.20
# of Samples	156	-	48	60	48
Segment V					
Mean ± s.d.	.474 ± .142	-	.535 ± .156	.469 ± .118	.410 ± .133
Range	.24 - .94	-	.34 - .94	.26 - .85	.24 - .75
# of Samples	136	-	42	58	36
Total Bay					
Mean ± s.d.	.544 ± .258	-	.614 ± .299	.533 ± .219	.481 ± .245
Range	.19 - 2.25	-	.320 - 2.25	.26 - 1.43	.19 - 2.20
# of Samples	647	-	203	261	183

1975

Segment 1					
Mean ± s.d.	.968 ± .589	1.035 ± .254	1.289 ± .701	.830 ± .508	.68 ± .477
Range	.34 - 2.74	.42 - 1.35	.52 - 2.74	.40 - 2.67	.34 - 2.00
# of Samples	84	11	26	30	17
Segment II					
Mean ± s.d.	.574 ± .245	.628 ± .173	.739 ± .270	.474 ± .174	.439 ± .119
Range	.18 - 1.49	.42 - 1.04	.35 - 1.49	.180 - 1.01	.25 - .81
# of Samples	216	13	80	75	48
Segment III					
Mean ± s.d.	.877 ± .492	1.36 ± 1.041	1.04 ± .477	.701 ± .258	.609 ± .164
Range	.31 - 2.87	.66 - 2.87	.40 - 2.03	.31 - 1.13	.38 - .87
# of Samples	44	4	17	16	7
Segment IV					
Mean ± s.d.	.418 ± .138	.474 ± .046	.473 ± .169	.38 ± .104	.378 ± .099
Range	.20 - 1.31	.43 - .53	.24 - 1.31	.20 - .92	.25 - .70
# of Samples	247	7	94	87	59
Segment V					
Mean ± s.d.	.461 ± .224	.795 ± .826	.539 ± .211	.395 ± .107	.388 ± .102
Range	.18 - 2.48	.43 - 2.48	.35 - 1.53	.23 - .78	.18 - .77
# of Samples	187	6	71	64	46
Total Bay					
Mean ± s.d.	.557 ± .343	.807 ± .516	.67 ± .396	.478 ± .259	.435 ± .20
Range	.18 - 2.87	.42 - 2.87	.24 - 2.74	.18 - 2.67	.18 - 2.00
# of Samples	778	41	288	272	177

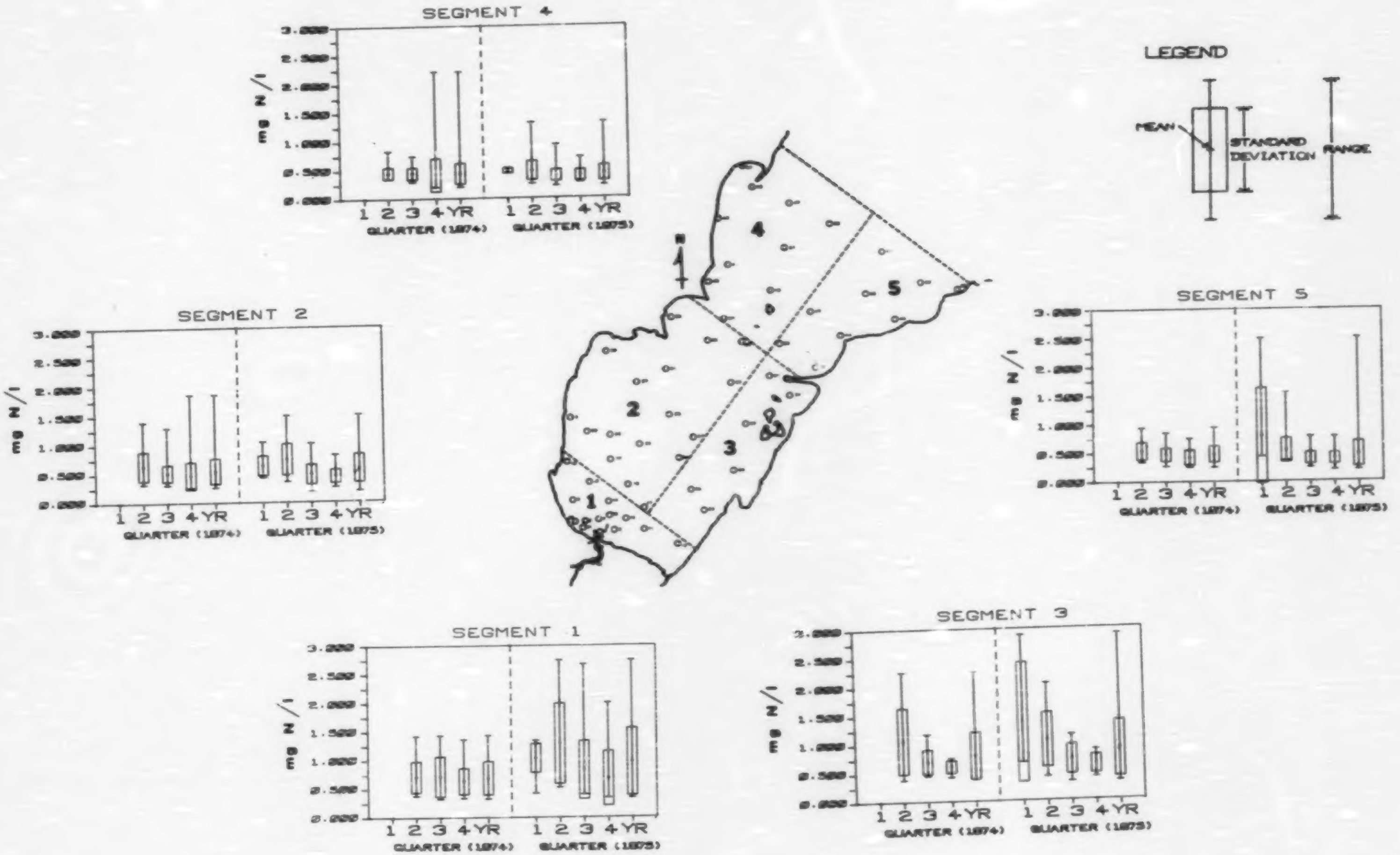


Figure 39. Data summary of total nitrogen (mg N/ℓ).

TABLE 30. DATA SUMMARY OF FILTERED REACTIVE PHOSPHATE-PHOSPHORUS (mg P/ℓ), PLOTTED IN FIGURE 40

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	.011 ± .015	.014 ± .013	.013 ± .018	.006 ± .003	.012 ± .017
Range	.001 - .100	.001 - .028	.002 - .100	.003 - .015	.002 - .093
# of Samples	208	6	97	69	36
Segment II					
Mean ± s.d.	.007 ± .010	.010 ± .005	.007 ± .011	.007 ± .010	.004 ± .001
Range	.002 - .099	.006 - .013	.002 - .077	.003 - .099	.002 - .009
# of Samples	280	2	122	109	47
Segment III					
Mean ± s.d.	.008 ± .017	.002 ± .002	.014 ± .027	.005 ± .002	.004 ± .001
Range	.001 - .100	.001 - .005	.002 - .100	.003 - .011	.002 - .005
# of Samples	67	5	25	26	11
Segment IV					
Mean ± s.d.	.004 ± .002	.002 ± .001	.004 ± .001	.005 ± .003	.003 ± .001
Range	.001 - .026	.001 - .004	.002 - .008	.003 - .026	.003 - .006
# of Samples	257	5	110	94	48
Segment V					
Mean ± s.d.	.005 ± .005	.002 ± .001	.005 ± .007	.004 ± .002	.004 ± 001
Range	.001 - .061	.001 - .004	.002 - .061	.003 - .013	.003 - .006
# of Samples	209	4	86	83	36
Total Bay					
Mean ± s.d.	.006 ± .009	.006 ± .009	.007 ± .013	.005 ± .003	.005 ± .008
Range	.001 - .100	.001 - .028	.002 - .100	.003 - .099	.002 - .093
# of Samples	1,024	23	442	381	178

1975

Segment 1					
Mean ± s.d.	.005 ± .008	.003 ± .001	.006 ± .006	.005 ± .011	.002 ± .001
Range	.001 - .047	.002 - .007	.001 - .022	.001 - .047	.001 - .003
# of Samples	73	10	23	26	14
Segment II					
Mean ± s.d.	.002 ± .001	.002 ± .002	.002 ± .001	.002 ± .001	.002 ± .001
Range	.001 - .009	.001 - .009	.001 - .006	.001 - .004	.001 - .003
# of Samples	214	12	80	75	47
Segment III					
Mean ± s.d.	.002 ± .001	.003 ± .002	.002 ± .001	.002 ± .001	.002 ± .0005
Range	.001 - .007	.001 - .007	.001 - .004	.001 - .003	.001 - .002
# of Samples	56	5	23	20	8
Segment IV					
Mean ± s.d.	.002 ± .001	.002 ± .002	.002 ± .001	.002 ± .002	.001 ± .0004
Range	.001 - .019	.001 - .005	.001 - .095	.001 - .019	.001 - .002
# of Samples	238	7	90	83	58
Segment V					
Mean ± s.d.	.002 ± .001	.001 ± .0005	.002 ± .002	.001 ± .0005	.001 ± .0006
Range	.001 - .010	.001 - .002	.001 - .010	.001 - .004	.001 - .003
# of Samples	189	6	72	65	46
Total Bay					
Mean ± s.d.	.002 ± .003	.002 ± .002	.002 ± .002	.002 ± .004	.002 ± .001
Range	.001 - .047	.001 - .009	.001 - .022	.001 - .047	.001 - .003
# of Samples	770	40	288	269	173

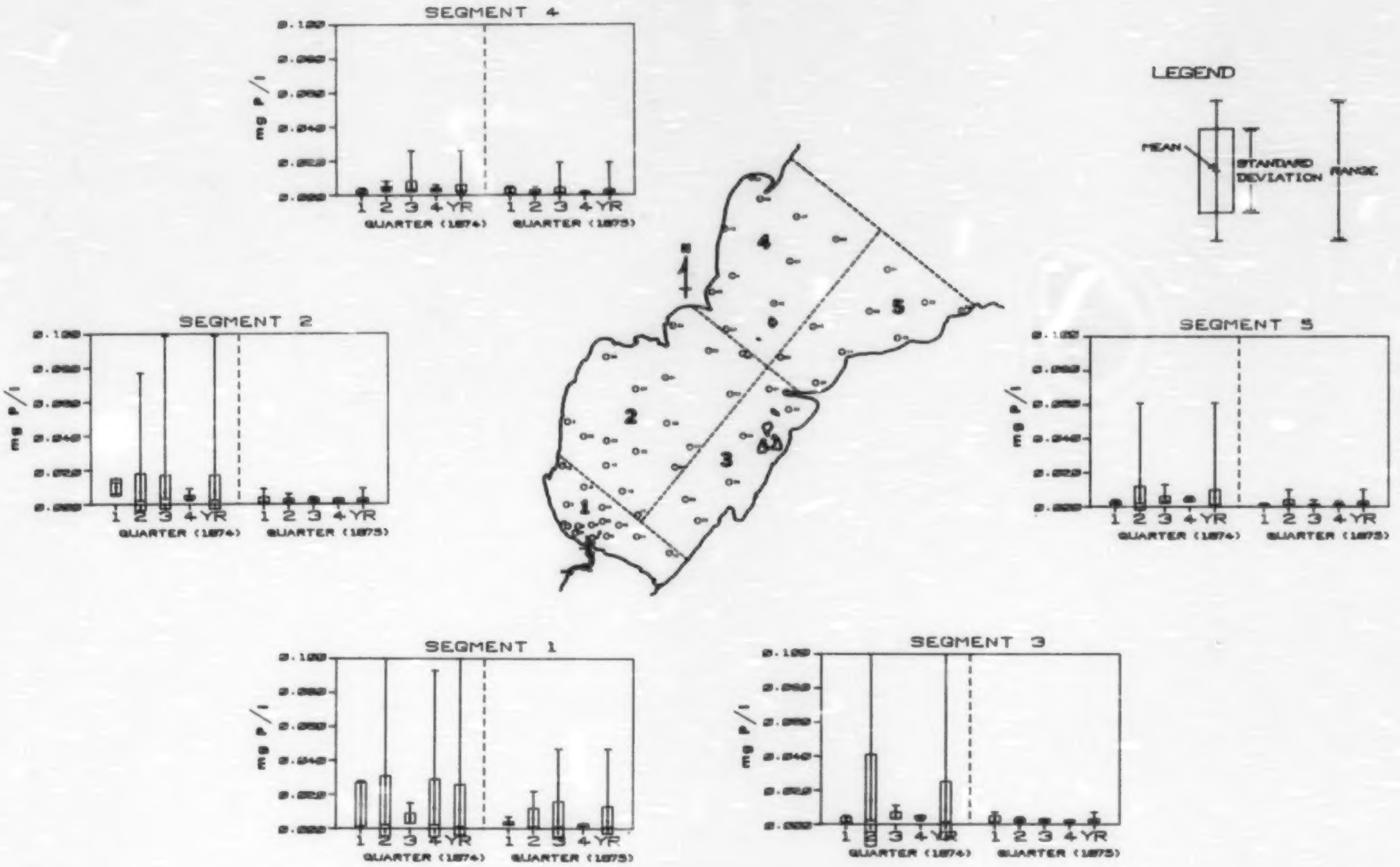


Figure 40. Data summary of filtered reactive phosphate-phosphorus (mg P/ℓ).

TABLE 31. DATA SUMMARY OF FILTERED TOTAL PHOSPHORUS (mg P/ℓ), PLOTTED IN FIGURE 41

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	.012 ± .016	.002 ± 0	.016 ± .018	.008 ± .006	.016 ± .022
Range	.002 - .125	.002	.002 - .070	.002 - .037	.002 - .125
# of Samples	115	4	33	42	36
Segment II					
Mean ± s.d.	.006 ± .003	.006 ± .006	.005 ± .002	.006 ± .003	.006 ± .003
Range	.002 - .018	.002 - .010	.002 - .010	.002 - .018	.003 - .015
# of Samples	183	2	60	74	47
Segment III					
Mean ± s.d.	.007 ± .005	.002 ± 0	.007 ± .003	.008 ± .006	.007 ± .003
Range	.002 - .033	.002	.003 - .016	.004 - .033	.008 - .013
# of Samples	54	5	18	20	11
Segment IV					
Mean ± s.d.	.005 ± .009	.037 ± .039	.003 ± .002	.005 ± .006	.004 ± .002
Range	.002 - .072	.002 - .072	.002 - .018	.002 - .044	.002 - .009
# of Samples	159	4	47	60	48
Segment V					
Mean ± s.d.	.004 ± .003	.002 ± .0006	.005 ± .005	.004 ± .002	.005 ± .003
Range	.002 - .035	.002 - .003	.002 - .035	.002 - .013	.003 - .014
# of Samples	145	3	48	58	36
Total Bay					
Mean ± s.d.	.006 ± .009	.010 ± .022	.006 ± .009	.006 ± .005	.007 ± .011
Range	.002 - .125	.002 - .072	.002 - .070	.002 - .044	.002 - .125
# of Samples	656	18	206	254	178

1975

Segment 1					
Mean ± s.d.	.014 ± .014	.007 ± .003	.016 ± .010	.018 ± .019	.010 ± .011
Range	.002 - .083	.002 - .011	.003 - .048	.004 - .083	.002 - .045
# of Samples	73	10	23	26	14
Segment II					
Mean ± s.d.	.007 ± .005	.004 ± .003	.007 ± .006	.006 ± .004	.008 ± .006
Range	.002 - .048	.002 - .012	.002 - .048	.002 - .021	.002 - .022
# of Samples	215	12	80	75	48
Segment III					
Mean ± s.d.	.006 ± .003	.005 ± .003	.006 ± .003	.006 ± .003	.009 ± .004
Range	.002 - .016	.002 - .009	.002 - .011	.002 - .012	.005 - .016
# of Samples	55	4	23	20	8
Segment IV					
Mean ± s.d.	.004 ± .004	.003 ± .002	.004 ± .003	.005 ± .005	.004 ± .003
Range	.002 - .044	.002 - .006	.002 - .032	.002 - .044	.002 - .016
# of Samples	239	7	90	84	58
Segment V					
Mean ± s.d.	.005 ± .003	.003 ± .001	.005 ± .003	.004 ± .002	.006 ± .006
Range	.002 - .034	.002 - .004	.002 - .032	.002 - .012	.002 - .034
# of Samples	190	6	72	66	46
Total Bay					
Mean ± s.d.	.007 ± .004	.004 ± .003	.006 ± .004	.006 ± .008	.006 ± .006
Range	.002 - .083	.002 - .012	.002 - .048	.002 - .083	.002 - .045
# of Samples	772	39	288	271	174

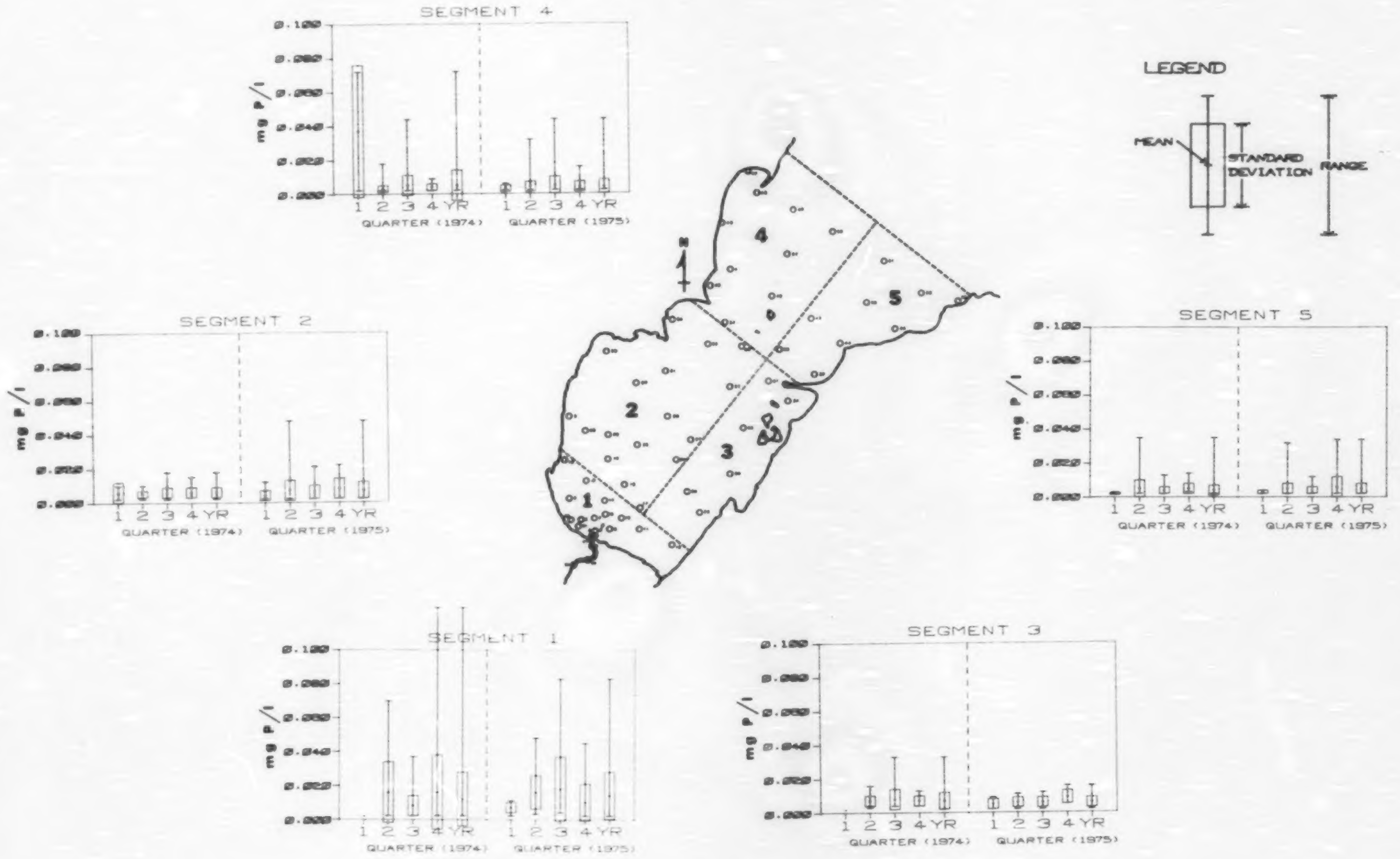


Figure 41. Data summary of filtered total phosphorus (mg P/ℓ).

Results showing the variation by cruise (at two depths) of u. tot. phosphorus at selected stations are given in Table 32 and Figure 42. Quarterly and annual summaries of all u. tot. P data compiled for each segment and the total bay are shown in Table 33 and Figure 43.

Twice-weekly u. tot. P data from four intake plants (plotted in Figure 44) are compared in Table 34 to regular cruise data for the same sites.

Sodium, unfiltered (u. Na)

The highest mean unfiltered sodium level of 46.64 mg Na/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 3.20 mg Na/ℓ was at station 50 (segment 4). The 1974-75 mean value of 9.00 mg Na/ℓ at station 20 and 29 was closest to the total bay mean of 9.74 mg Na/ℓ.

Mean values by segment ranged from 3.6 mg Na/ℓ (segment 4, 1974) to 11.7 mg Na/ℓ (segment 1, 1974). The greatest annual range, 5.0 mg Na/ℓ - 50.0 mg Na/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 7.9 mg Na/ℓ in segment 2 was closest to the total bay of 7.0 mg Na/ℓ.

Quarterly and annual summaries of all u. sodium data compiled for each segment and the total bay are shown in Table 35 and Figure 45.

Potassium, unfiltered (u. K)

The highest mean unfiltered potassium level of 4.32 mg K/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 0.87 mg K/ℓ was at station 51 (segment 5). The 1974-75 mean value of 1.60 mg K/ℓ at station 20 was closest to the total bay mean of 1.58 mg K/ℓ.

Mean values by segment ranged from 0.9 mg K/ℓ (segment 4, 1974) to 1.9 mg K/ℓ (segments 1 and 3, 1974). The greatest annual range, 1.1. mg K/ℓ - 5.6 mg K/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 1.5 mg K/ℓ in segment 2 was closest to the total bay mean of 1.4 mg K/ℓ.

Quarterly and annual summaries of all u. potassium data compiled for each segment and the total bay are shown in Table 36 and Figure 46.

Calcium, unfiltered (u. Ca)

The highest mean unfiltered calcium level of 89.86 mg Ca/ℓ during 1974-75 was recorded at station 55 (river). The lowest of 27.9 mg Ca/ℓ was at station 51 (segment 5). The 1974-75 mean value of 40.92 mg Ca/ℓ at station 2 was closest to the total bay mean of 40.89 mg Ca/ℓ.

Mean values by segment ranged from 29.8 mg Ca/ℓ (segment 4, 1974) to 46.3 mg Ca/ℓ (segment 1, 1974). The greatest annual range, 28.0 mg Ca/ℓ - 104.0 mg Ca/ℓ, occurred in segment 1 (1974). In 1974 the mean value of 40.5 mg Ca/ℓ in segment 2 was closest to the total bay mean of 37.0 mg Ca/ℓ.

TABLE 32. UNFILTERED TOTAL PHOSPHORUS (mg P/ℓ) AT SELECTED STATIONS, PLOTTED IN FIGURE 42

Station Number	Location	Depth In Meters	Mean* (Range)	Standard Deviation	Minimum Date	Maximum Date
55	River	1	0.251 (0.185-0.341)	0.050	75-11-16	75-4-11
		8	0.283 (0.121-0.665)	0.111	75-4-11	75-7-29
8	Segment I	1	0.060 (0.017-0.110)	0.030	75-7-31	75-12-16
		3	0.044 (0.006-0.078)	0.021	75-10-11	74-12-17
35	Segment II	1	0.014 (0.002-0.059)	0.011	75-9-23	75-9-3
		10	0.013 (0.004-0.032)	0.008	74-7-8	75-9-3
34	Segment III	1	0.034 (0.008-0.048)	0.013	75-2-19	75-8-20
		3	0.037 (0.026-0.052)	0.009	75-5-22	75-6-8
49	Segment IV	1	0.005 (0.002-0.017)	0.003	74-12-18	75-6-26
		20	0.008 (0.002-0.089)	0.019	74-4-20	74-10-7
51	Segment V	1	0.006 (0.002-0.048)	0.009	75-7-30	74-2-20
		28	0.004 (0.003-0.008)	0.002	74-8-14	75-8-19

*Mid-winter data included for 1 m depth only.

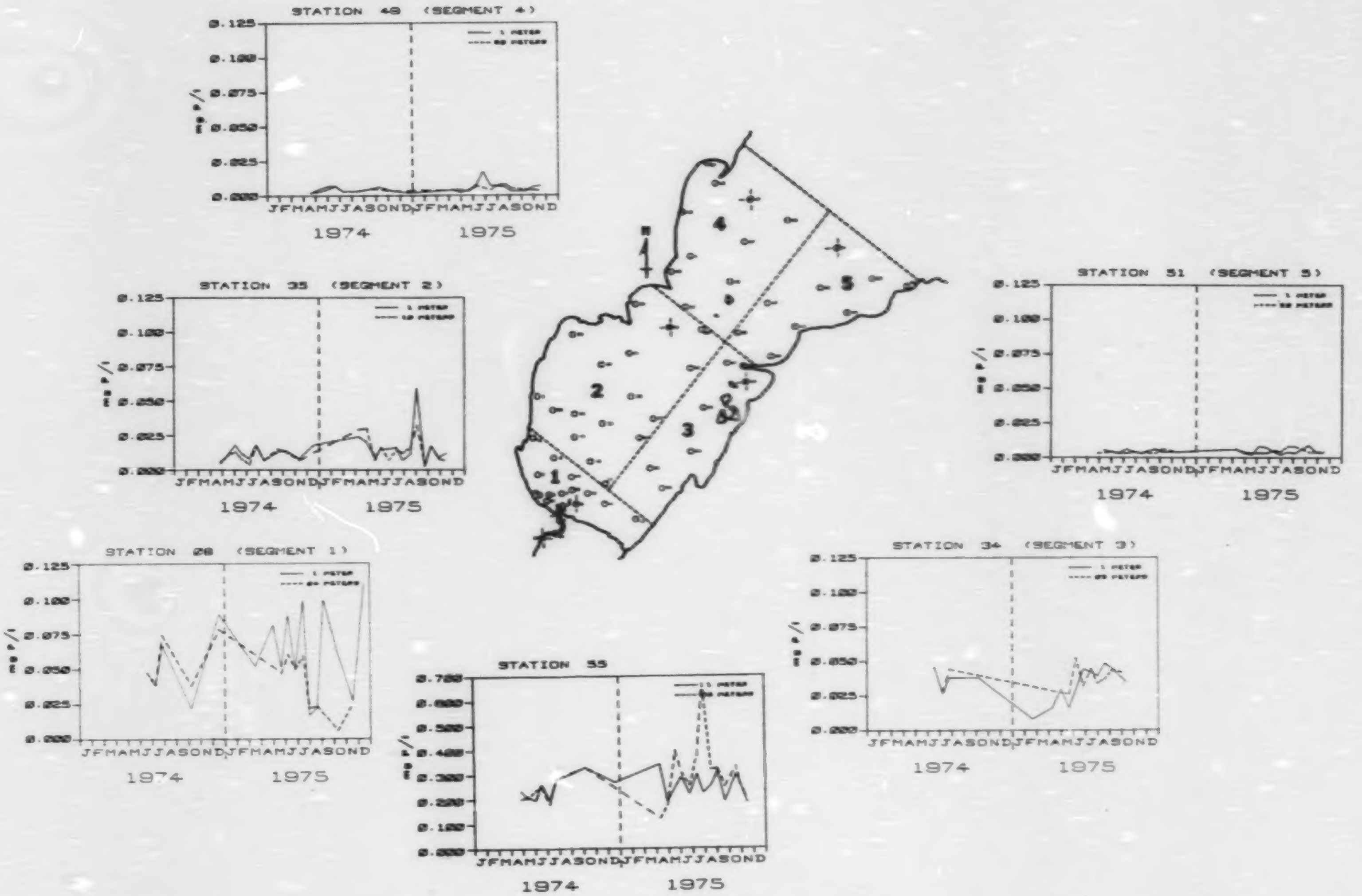


Figure 42. Unfiltered total phosphorus (mg P/ℓ) at selected stations (+).

TABLE 33. DATA SUMMARY OF UNFILTERED TOTAL PHOSPHORUS (mg P/ℓ), PLOTTED IN FIGURE 43

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	.058 ± .039	-	.071 ± .052	.054 ± .028	.050 ± .034
Range	.002 - .290	-	.002 - .290	.013 - .118	.004 - .160
# of Samples	109	-	32	42	35
Segment II					
Mean ± s.d.	.026 ± .013	-	.024 ± .013	.027 ± .014	.026 ± .012
Range	.003 - .069	-	.003 - .057	.004 - .069	.007 - .069
# of Samples	180	-	58	75	47
Segment III					
Mean ± s.d.	.037 ± .015	-	.046 ± .018	.030 ± .010	.038 ± .013
Range	.011 - .081	-	.021 - .081	.012 - .050	.011 - .059
# of Samples	47	-	16	20	11
Segment IV					
Mean ± s.d.	.009 ± .010	-	.008 ± .009	.007 ± .008	.010 ± .013
Range	.002 - .089	-	.002 - .042	.002 - .050	.002 - .089
# of Samples	157	-	48	61	48
Segment V					
Mean ± s.d.	.013 ± .016	-	.016 ± .013	.009 ± .007	.011 ± .009
Range	.002 - .048	-	.002 - .048	.002 - .031	.003 - .038
# of Samples	142	-	48	58	36
Total Bay					
Mean ± s.d.	.025 ± .027	-	.028 ± .033	.023 ± .022	.024 ± .024
Range	.002 - .290	-	.002 - .290	.002 - .118	.002 - .160
# of Samples	635	-	202	256	177

1975

Segment 1					
Mean ± s.d.	.058 ± .029	.040 ± .013	.069 ± .025	.060 ± .035	.047 ± .023
Range	.006 - .160	.008 - .056	.034 - .140	.017 - .160	.006 - .110
# of Samples	72	10	23	25	14
Segment II					
Mean ± s.d.	.024 ± .014	.015 ± .012	.026 ± .015	.023 ± .013	.026 ± .010
Range	.002 - .077	.002 - .043	.007 - .077	.002 - .062	.006 - .043
# of Samples	214	12	80	74	48
Segment III					
Mean ± s.d.	.032 ± .013	.024 ± .014	.028 ± .013	.034 ± .011	.041 ± .009
Range	.005 - .055	.008 - .038	.005 - .052	.014 - .048	.028 - .055
# of Samples	54	4	22	20	8
Segment IV					
Mean ± s.d.	.008 ± .008	.004 ± .002	.008 ± .007	.009 ± .008	.008 ± .007
Range	.002 - .050	.002 - .008	.002 - .050	.002 - .040	.002 - .033
# of Samples	237	7	87	85	58
Segment V					
Mean ± s.d.	.011 ± .009	.004 ± .002	.009 ± .007	.012 ± .011	.012 ± .009
Range	.002 - .071	.002 - .007	.002 - .032	.002 - .071	.003 - .040
# of Samples	190	6	72	66	46
Total Bay					
Mean ± s.d.	.020 ± .021	.019 ± .018	.020 ± .021	.021 ± .022	.020 ± .017
Range	.002 - .160	.002 - .056	.002 - .140	.002 - .160	.002 - .110
# of Samples	767	39	284	272	174

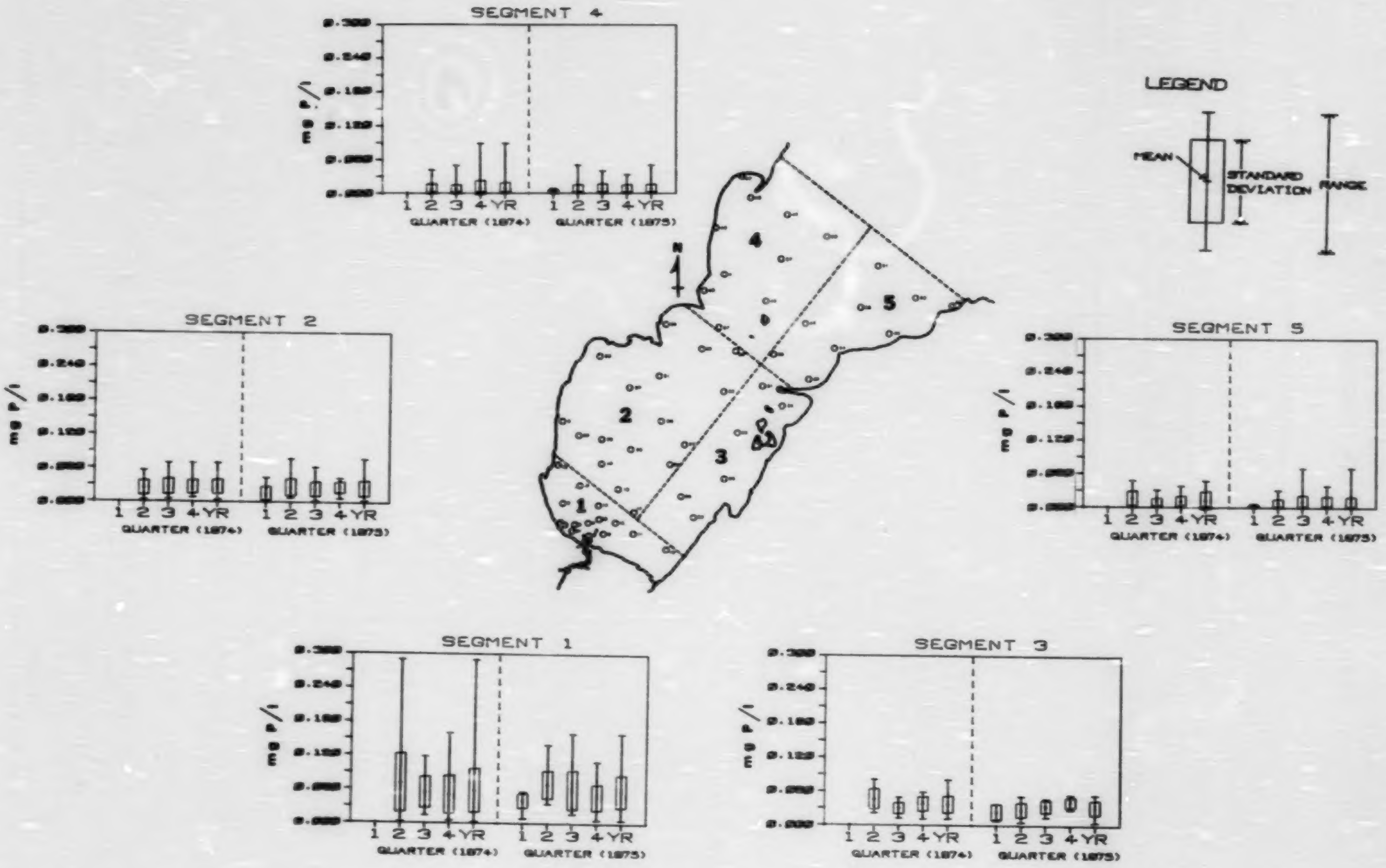


Figure 43. Data summary of unfiltered total phosphorus (mg P/ℓ).

TABLE 34. MEAN UNFILTERED TOTAL PHOSPHORUS VALUES (mg/ℓ) FROM CRUISE (SB) AND INTAKE PLANT (SBI) SAMPLES, PLOTTED IN FIGURE 44

		Station							
		Saginaw River		Kawkawlin		Pinconning		Whitestone Point	
	Month	SB 1	SBI 1	SB 2	SBI 2	SB 3	SBI 3	SB 4	SBI 4
1974	1	--	0.226	--	--	--	--	--	0.004
	2	--	0.159	--	--	--	--	--	0.006
	3	--	0.131	--	--	--	--	--	0.008
	4	0.244	0.171	0.040	--	--	--	--	0.006
	5	0.233	0.184	0.040	--	--	--	--	0.003
	6	0.222	0.227	0.032	--	0.037	--	0.028	0.004
	7	0.205	0.214	0.047	--	0.039	--	0.007	0.008
	8	--	0.234	0.037	--	--	--	--	0.011
	9	--	0.243	--	--	--	--	--	0.008
	10	0.220	0.186	0.042	--	0.043	--	0.004	0.008
	11	--	0.215	--	--	--	--	0.007	--
	12	0.294	0.242	0.026	0.023		--		0.006
1975	1	--	0.220	--	0.014	--	--	--	0.004
	2	0.274	0.250	--	0.013	0.008	0.013	--	0.004
	3	0.240	0.198	0.065	0.049	--	0.026	--	0.006
	4	0.204	0.183	0.094	0.078	0.026	0.045	0.006	0.011
	5	0.213	0.164	0.056	0.074	0.046	0.036	0.003	0.006
	6	0.230	0.176	0.039	0.047	0.036	0.043	0.007	0.008
	7	0.271	0.149	0.046	0.040	0.028	0.046	0.007	0.009
	8	0.213	0.096	0.039	0.031	0.031	0.050	0.010	0.008
	9	0.179	0.165	0.100	0.046	0.057	0.053	0.010	0.005
	10	0.271	0.178	0.042	0.041	0.059	0.044	0.005	0.004
	11	0.240	0.184	0.036	--	0.020	--	0.004	--
	12	--	0.180	0.071	--	--	--	--	--

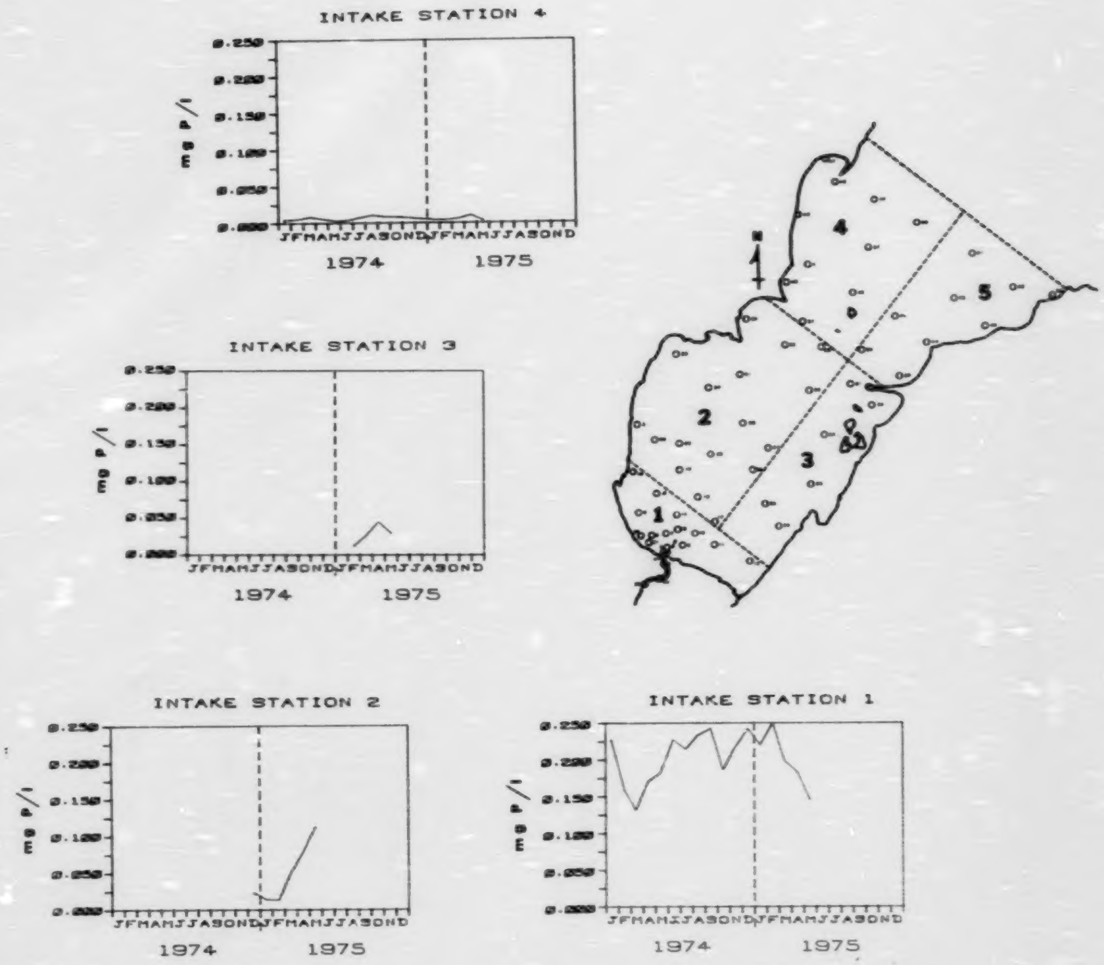


Figure 44. Unfiltered total phosphorus (mg P/ℓ) in twice-weekly samples from water intake plants (equivalent to stations 1, 2, 3, 4).

TABLE 35. DATA SUMMARY OF UNFILTERED SODIUM (mg Na/ℓ), PLOTTED IN FIGURE 45

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment I					
Mean ± s.d.	11.7 ± 7.3	9.5 ± 2.4	12.5 ± 7.9	10.5 ± 4.3	12.4 ± 10.4
Range	5.0 - 50.0	6.0 - 11.0	6.0 - 50.0	5.0 - 20.0	5.0 - 45.0
# of Samples	134	4	64	46	20
Segment II					
Mean ± s.d.	7.9 ± 2.0	9.0 ± 0	9.0 ± 1.6	6.8 ± 2.0	7.2 ± 1.6
Range	5.0 - 13.0	9.0	6.0 - 13.0	5.0 - 11.0	6.0 - 9.0
# of Samples	43	2	18	18	5
Segment III					
Mean ± s.d.	11.0 ± 2.7	10.3 ± 3.2	12.1 ± 3.5	10.5 ± 1.3	9.6 ± 2.1
Range	7.0 - 18.0	8.0 - 14.0	7.0 - 18.0	8.0 - 13.0	7.0 - 12.0
# of Samples	37	3	15	14	5
Segment IV					
Mean ± s.d.	3.6 ± 1.1	4.8 ± 1.7	3.8 ± 1.4	3.5 ± .6	3.2 ± .4
Range	3.0 - 11.0	3.0 - 7.0	3.0 - 11.0	3.0 - 5.0	3.0 - 4.0
# of Samples	163	4	76	55	28
Segment V					
Mean ± s.d.	4.2 ± 1.6	4.3 ± .5	4.5 ± 2.1	4.0 ± 1.4	4.1 ± 1.3
Range	3.0 - 10.0	4.0 - 5.0	3.0 - 10.0	3.0 - 8.0	3.0 - 7.0
# of Samples	87	4	32	35	16
Total Bay					
Mean ± s.d.	7.0 ± 5.5	7.2 ± 3.2	7.7 ± 6.2	6.5 ± 4.0	6.6 ± 6.7
Range	3 - 50	3 - 14	3 - 50	3 - 20	3 - 45
# of Samples	464	17	205	168	74

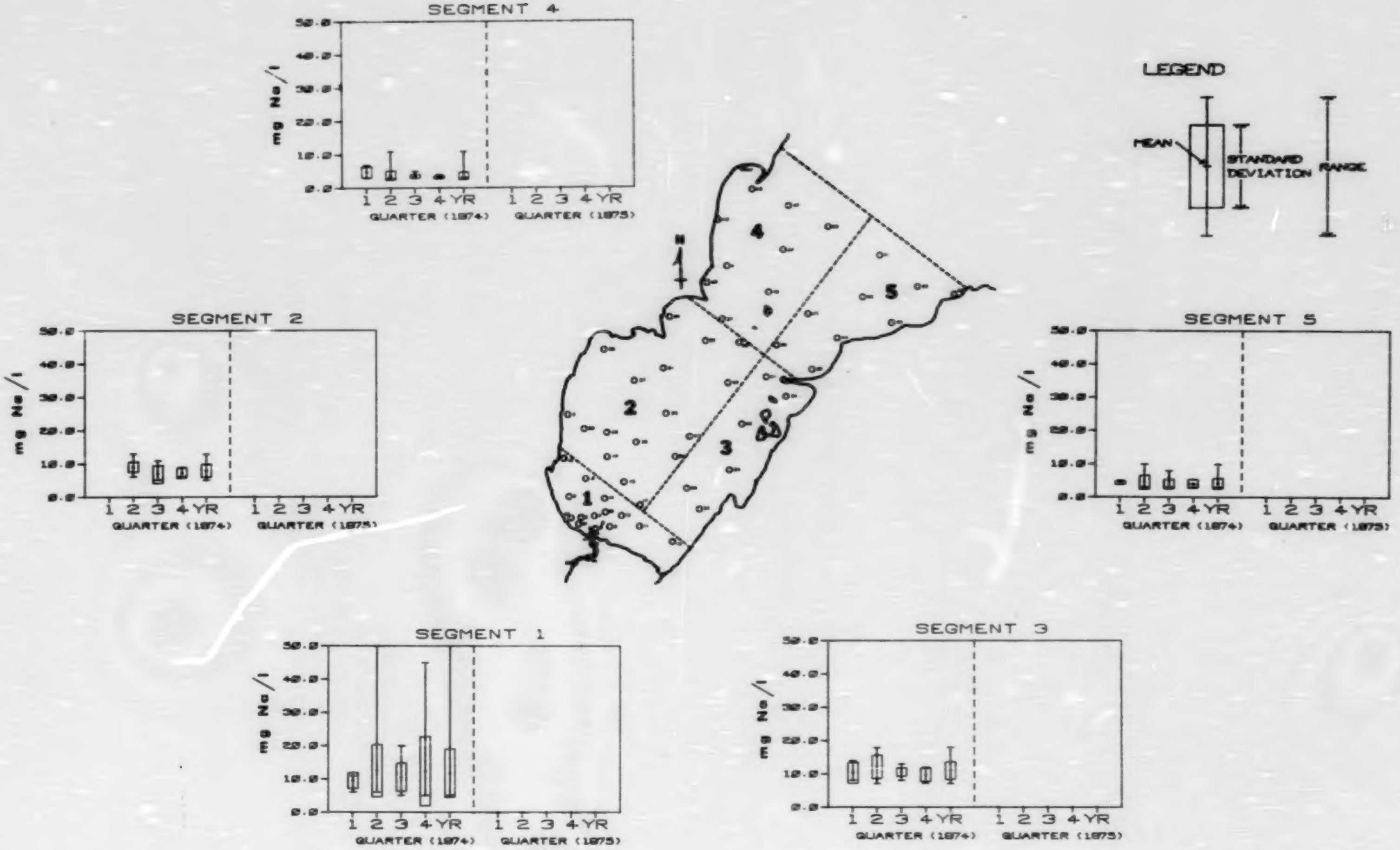


Figure 45. Data summary of unfiltered sodium (mg Na/ℓ).

TABLE 36. DATA SUMMARY OF UNFILTERED POTASSIUM (mg K/ℓ), PLOTTED IN FIGURE 46

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	1.9 ± 0.7	2.2 ± .5	2.1 ± .9	1.7 ± .3	1.8 ± .8
Range	1.1 - 5.6	1.6 - 2.7	1.2 - 5.6	1.2 - 2.3	1.1 - 4.0
# of Samples	134	4	64	46	20
Segment II					
Mean ± s.d.	1.5 ± .3	1.9 ± .4	1.7 ± .3	1.3 ± .2	1.3 ± .1
Range	.9 - 2.2	1.6 - 2.2	1.2 - 2.2	.9 - 1.8	1.2 - 1.4
# of Samples	43	2	18	18	5
Segment III					
Mean ± s.d.	1.9 ± .5	1.8 ± .4	2.2 ± .6	1.8 ± .2	1.5 ± .2
Range	1.2 - 3.1	1.4 - 2.2	1.2 - 3.1	1.2 - 2.1	1.3 - 1.7
# of Samples	37	3	15	14	5
Segment IV					
Mean ± s.d.	.9 ± .1	1.1 ± .1	.9 ± .2	.9 ± .1	.9 ± .1
Range	.7 - 1.7	1.0 - 1.2	.7 - 1.7	.7 - 1.4	.8 - 1.2
# of Samples	163	4	76	55	28
Segment V					
Mean ± s.d.	1.0 ± .2	1.0 ± 0	1.1 ± .3	1.0 ± .2	.9 ± .1
Range	.7 - 1.6	1.0	.7 - 1.6	.8 - 1.4	.8 - 1.2
# of Samples	87	4	32	35	16
Total Bay					
Mean ± s.d.	1.4 ± .6	1.5 ± .6	1.5 ± .8	1.3 ± .4	1.2 ± .6
Range	.7 - 5.6	1.0 - 2.7	.7 - 5.6	.7 - 2.3	.8 - 4.0
# of Samples	464	17	205	168	74

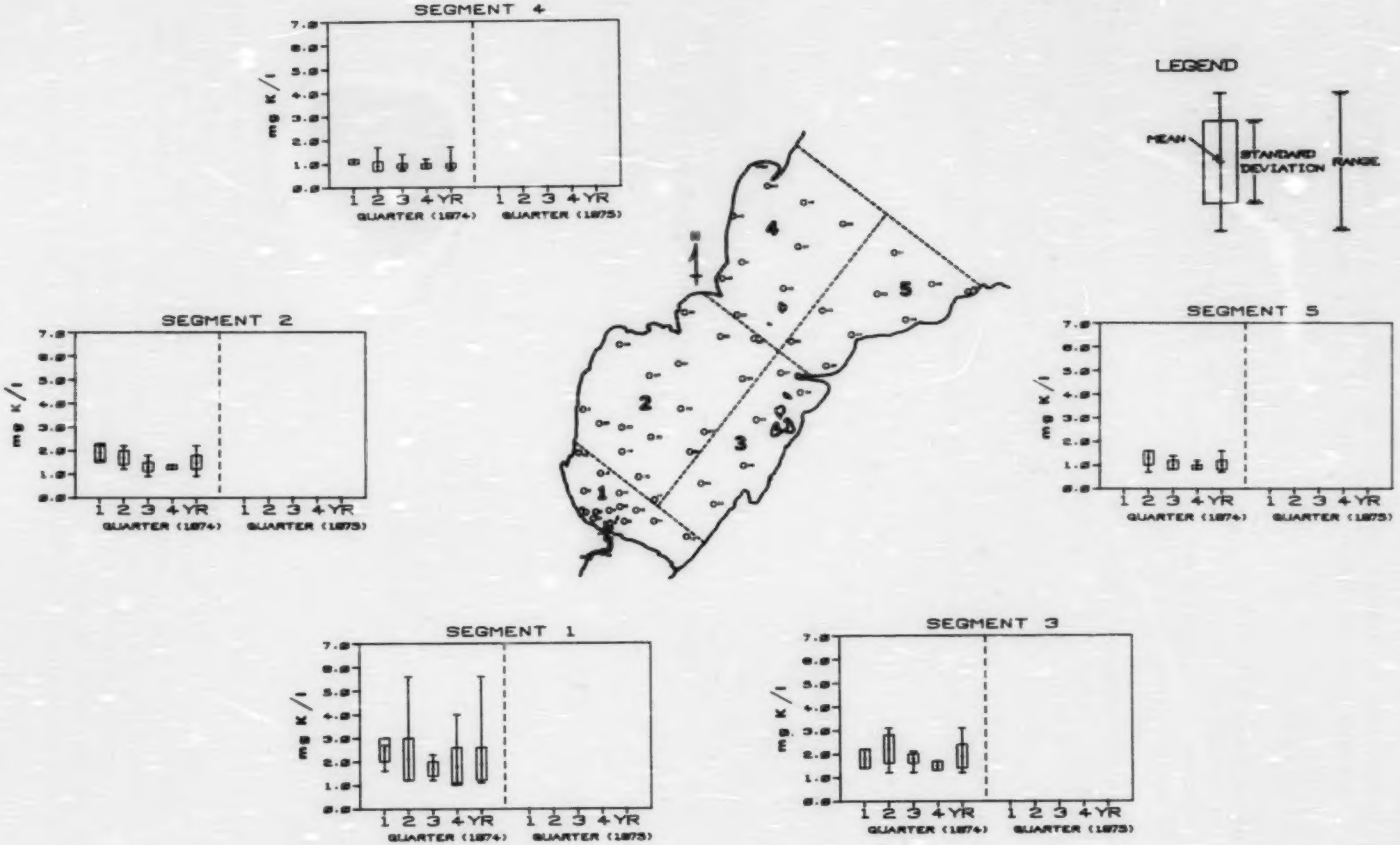


Figure 46. Data summary of unfiltered potassium (mg K/ℓ).

Quarterly and annual summaries of all u. calcium data compiled for each segment and the total bay are shown in Table 37 and Figure 47.

Magnesium, unfiltered

The highest mean unfiltered magnesium level of 21.27 mg Mg/ℓ during 1974-75 was recorded at station 55 (river). The lowest level of 7.00 mg Mg/ℓ was at station 47 (segment 4). The 1974-75 mean value of 9.90 mg Mg/ℓ at station 16 was closest to the total bay mean of 9.95 mg Mg/ℓ.

Mean values by segment ranged from 7.4 mg Mg/ℓ (segment 4, 1974) to 12.1 mg Mg/ℓ (segment 3, 1974). The greatest annual range, 8.0 mg Mg/ℓ - 35.0 mg Mg/ℓ, occurred in segment 3 (1974). In 1974 the mean value of 9.6 mg Mg/ℓ in segment 2 was closest to the total bay mean of 9.1 mg Mg/ℓ.

Quarterly and annual summaries of all u. magnesium data compiled for each segment and the total bay are shown in Table 38 and Figure 48.

PARAMETER CORRELATIONS

The following show some results of correlation and multiple regression analyses of the data. As a first step, matrices of correlation coefficients were generated using all combinations of parameter pairs. This was done for all the data groupings described earlier as well as for the total aggregate of data. One example is shown in Table 39. In this matrix the only coefficients shown are those significant at the 99% level, all representing a high degree of correlation.

Selected results of the correlation analysis are also shown in Figures 49-53, in which the variations of Zr/Sz for chlorophyll *a* vs. other key parameters are plotted against time in each bay segment. In this format the time and place of significant correlations are readily apparent.

Multiple regression analysis was also used to examine the "dependence" of chlorophyll *a* levels on phosphorus and nitrogen species, as shown in Tables 40 and 41. Table 42 shows how these relationships varied in each of the bay segments during 1974 and 1975.

Cooperative Studies

Remote Sensing --

These results also have been used to support a study conducted by Bendix Aerospace Systems Division in Ann Arbor, Michigan. The project, entitled "Application of Landsat to the Surveillance and Control of Lake Eutrophication in the Great Lakes Basin", was supported by Contract NAS 5-20942 from the National Aeronautics and Space Administration (NASA). The objectives of that part of the study related to Saginaw Bay were to use satellite multispectral data to estimate levels of various water quality factors and to map their distribution throughout the bay. Thus, Landsat surveillance was in-

TABLE 37. DATA SUMMARY OF UNFILTERED CALCIUM (mg Ca/ℓ), PLOTTED IN FIGURE 47

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment 1					
Mean ± s.d.	46.3 ± 13.3	54.8 ± 10.7	53.2 ± 14.4	38.8 ± 4.4	39.7 ± 11.3
Range	28.0-104.0	44.0 - 69.0	35.0 - 104.0	31.0 - 53.0	28.0 - 69.0
# of Samples	134	4	64	46	20
Segment II					
Mean ± s.d.	40.5 ± 7.1	47.5 ± .7	46.2 ± 5.3	36.0 ± 4.6	33.8 ± 1.1
Range	30.0 - 58.0	47.0 - 48.0	38.0 - 58.0	30.0 - 45.0	32.0 - 35.0
# of Samples	43	2	18	18	5
Segment III					
Mean ± s.d.	46.2 ± 10.4	56.7 ± 12.1	54.2 ± 8.5	38.6 ± 2.8	37.4 ± 1.1
Range	33.0 - 72.0	44.0 - 68.0	36.0 - 72.0	33.0 - 42.0	36.0 - 39.0
# of Samples	37	3	15	14	5
Segment IV					
Mean ± s.d.	29.8 ± 3.7	36.3 ± 6.1	31.3 ± 3.7	28.9 ± 2.5	26.3 ± 1.0
Range	24.0 - 46.0	32.0 - 45.0	26.0 - 46.0	24.0 - 36.0	25.0 - 29.0
# of Samples	163	4	76	55	28
Segment V					
Mean ± s.d.	30.5 ± 4.6	35.3 ± 1.9	32.5 ± 5.5	29.6 ± 3.5	27.4 ± 2.0
Range	25.0 - 43.0	34.0 - 38.0	26.0 - 43.0	25.0 - 40.0	26.0 - 32.0
# of Samples	87	4	32	35	16
Total Bay					
Mean ± s.d.	37.0 ± 11.5	45.3 ± 11.8	41.3 ± 13.7	33.3 ± 5.8	31.4 ± 8.4
Range	24 - 104	32 - 69	26 - 104	24 - 53	25 - 69
# of Samples	464	17	205	168	74

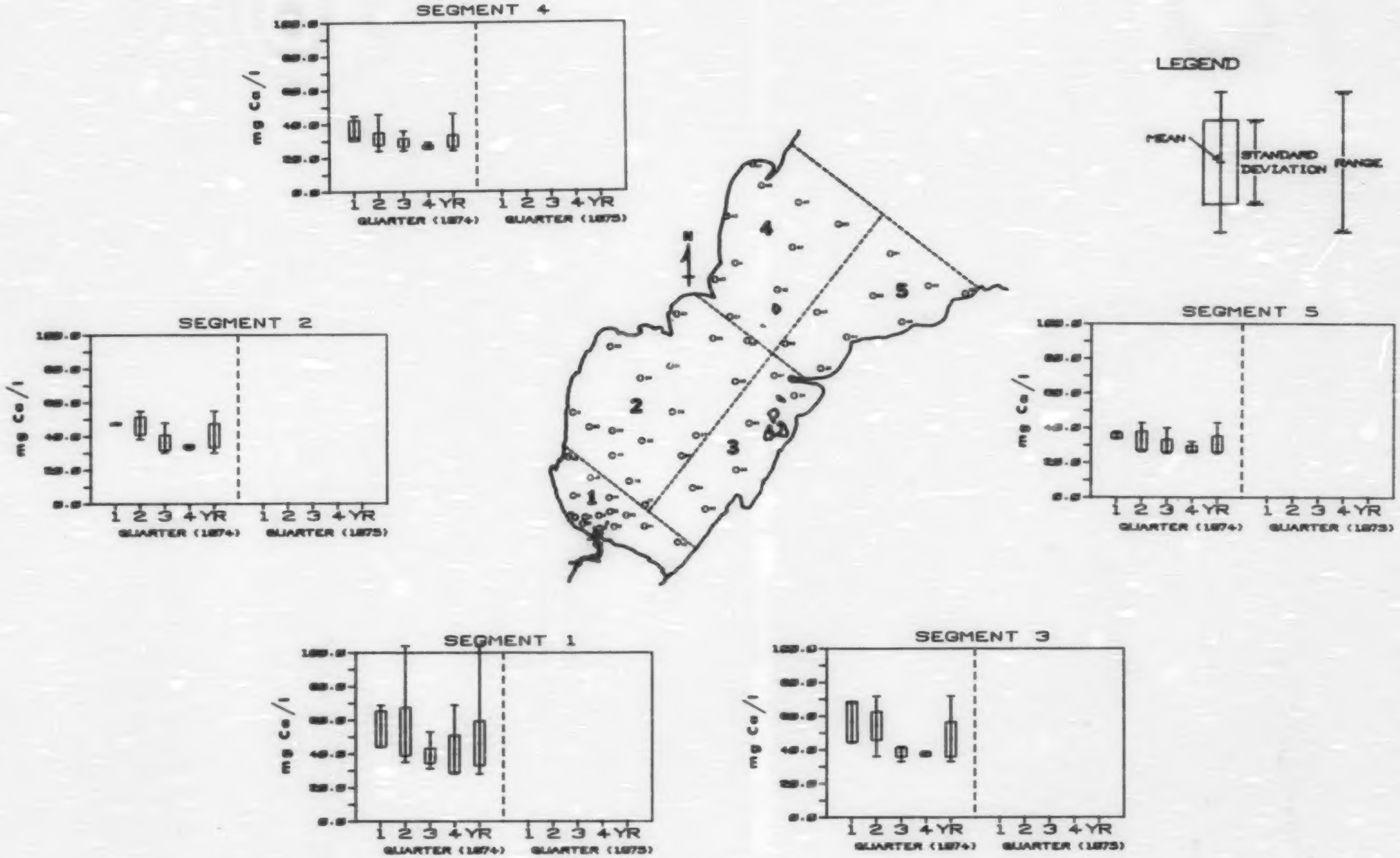


Figure 47. Data summary of unfiltered calcium (mg Ca/ℓ).

TABLE 38. DATA SUMMARY OF UNFILTERED MAGNESIUM (mg Mg/ℓ), PLOTTED IN FIGURE 48

1974

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-A)	4th(S-D)
Segment I					
Mean ± s.d.	11.0 ± 2.5	11.5 ± 1.7	11.7 ± 2.8	10.3 ± 1.4	10.1 ± 2.6
Range	6.0 - 20.0	10.0 - 13.0	6.0 - 20.0	8.0 - 14.0	8.0 - 16.0
# of Samples	134	4	64	46	20
Segment II					
Mean ± s.d.	9.6 ± 1.1	9.5 ± .7	10.3 ± 1.3	9.1 ± .7	8.6 ± .5
Range	8.0 - 13.0	9.0 - 10.0	9.0 - 13.0	8.0 - 10.0	8.0 - 9.0
# of Samples	43	2	18	18	5
Segment III					
Mean ± s.d.	12.1 ± 4.3	11.7 ± 2.5	12.5 ± 1.9	10.7 ± .9	14.8 ± 11.3
Range	8.0 - 35.0	9.0 - 14.0	8.0 - 16.0	9.0 - 12.0	9.0 - 35.0
# of Samples	37	3	15	14	5
Segment IV					
Mean ± s.d.	7.4 ± .9	7.0 ± 1.4	7.4 ± .8	7.5 ± .5	7.2 ± 1.3
Range	6.0 - 14.0	6.0 - 9.0	6.0 - 11.0	7.0 -9.0	6.0 - 14.0
# of Samples	161	4	70	55	28
Segment V					
Mean ± s.d.	7.7 ± .9	8.0 ± 0	7.9 ± 1.1	7.8 ± .9	7.4 ± .7
Range	6.0 - 10.0	8.0	6.0 - 10.0	7.0 - 10.0	7.0 - 9.0
# of Samples	87	4	32	35	16
Total Bay					
Mean ± s.d.	9.1 ± 2.6	9.4 ± 2.4	9.5 ± 2.8	8.8 ± 1.6	8.6 ± 3.7
Range	6 - 35	6 - 14	6 - 20	7 - 14	6 - 35
# of Samples	464.	17	205	168	74

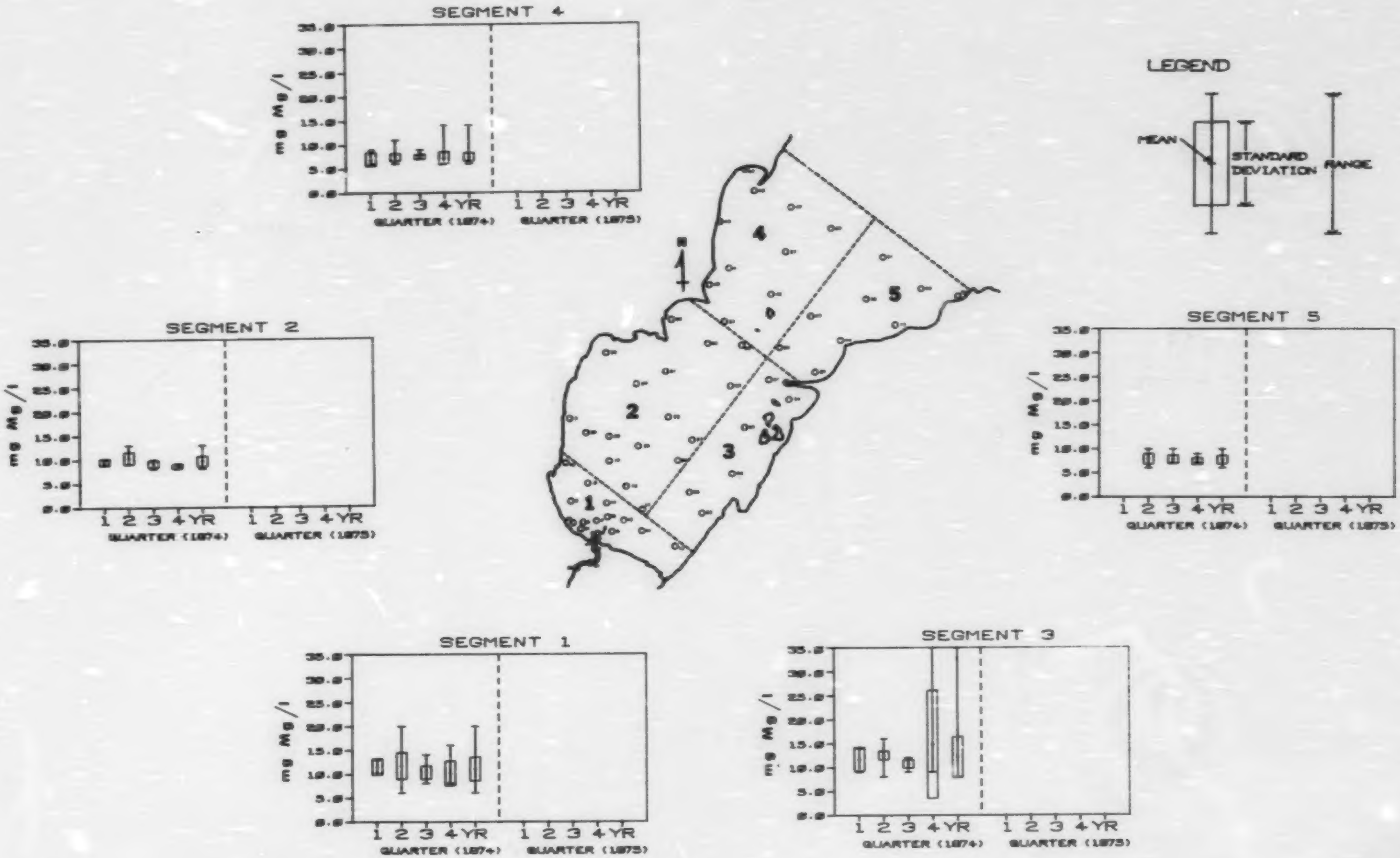


Figure 48. Data summary of unfiltered magnesium (mg Mg/ℓ).

TABLE 39. CORRELATION COEFFICIENTS FOR SELECTED PARAMETERS. DATA FROM TOTAL BAY, YEAR 1974

	Temperature	Dissolved Oxygen	Secchi Depth	pH	Tot. Alkalinity	Sp. Conductivity	F. Chloride	Nf. Chlorophyll a	U. Sodium	U. Potassium	U. Magnesium	U. Calcium	F. Tot. Ammonia	F. Reac. Phosphorus	F. Reac. Silicates	F. NO_3 + NO_2 Nitrogen	F. Tot. Phosphorus	U. Kjel. Nitrogen	U. Tot. Phosphorus
Temperature	1.0000																		
Dissolved Oxygen	-.6356 (725)	1.0000																	
Secchi Depth		.1624	1.0000																
pH			.5973 (450)	1.0000															
Tot. Alkalinity			.5005 (468)	.4651 (825)	1.0000														
Sp. Conductivity	.0957 (964)	-.2131 (668)	-.3309 (506)		.3081 (872)	1.0000													
F. Chloride	.1262 (969)	-.2019 (690)	-.3541 (512)		.2626 (860)	.7889 (945)	1.0000												
Nf. Chlorophyll a	.2572 (793)	-.2015 (629)	-.4174 (439)		.1767 (682)	.5764 (760)	.6483 (780)	1.0000											
U. Sodium	.2191 (476)	-.3737 (334)	-.4576 (229)	.1424 (424)	.3689 (425)	.9091 (473)	.9279 (486)	.6658 (379)	1.0000										
U. Potassium	.1854 (476)	-.3785 (334)	-.4943 (229)	.1369 (424)	.4147 (425)	.9172 (473)	.8811 (486)	.6484 (379)	.9218 (496)	1.0000									
U. Magnesium	.2141 (476)	-.3612 (334)	-.4744 (229)	.2009 (424)	.3656 (425)	.7919 (473)	.7565 (486)	.6817 (379)	.7892 (496)	.8266 (496)	1.0000								
U. Calcium		-.3055 (334)	-.4606 (229)	.1444 (424)	.4052 (425)	.8896 (473)	.7932 (486)	.5192 (379)	.8258 (496)	.9095 (496)	.7827 (496)	1.0000							
F. Tot. Ammonia	.1887 (888)	-.2921 (616)				.1851 (871)	.1911 (887)		.2100 (429)	.2489 (429)	.1712 (429)	.1838 (838)	1.0000						
F. Reac. Phosphorus		-.1524 (453)			.1387 (587)	.3848 (647)	.3600 (647)		.5494 (315)	.5802 (315)	.3763 (315)	.5122 (654)	.2501 (453)	1.0000					
F. Reac. Silicates						-.1860 (951)	.2340 (954)	-.1345 (763)	-.2550 (473)	-.2195 (473)	-.2153 (473)	-.2539 (965)	.1066 (683)		1.0000				
F. NO_3+NO_2 Nitrogen	-.3661 (758)	.2279 (561)	-.1682 (374)		.1690 (658)	.4703 (735)	.3206 (744)	.3245 (635)	.3353 (379)	.4944 (379)	.4786 (379)	.5512 (758)	.1243 (561)	.2172 (374)		1.0000			
F. Tot. Phosphorus						.4037 (456)	.4729 (460)		.5679 (218)	.4665 (218)	.2739 (218)	.4333 (460)	.5274 (322)	.5301 (270)			1.0000		
U. Kjel. Nitrogen	.3100 (622)	-.1536 (409)	-.3199 (323)			.4425 (610)	.4998 (616)	.7330 (444)	.5866 (307)	.5312 (307)	.4992 (307)	.3913 (622)	.1372 (409)				.2573 (616)	1.0000	
U. Tot. Phcsphorus	.1659 (575)	-.2084 (382)	-.3392 (308)		.2094 (465)	.6359 (564)	.6507 (571)	.5604 (407)	.7263 (268)	.7326 (268)	.6151 (268)	.7181 (575)	.3355 (382)	.3432 (308)	-.1862 (477)	.3569 (465)	.5031 (571)	.4990 (407)	1.0000

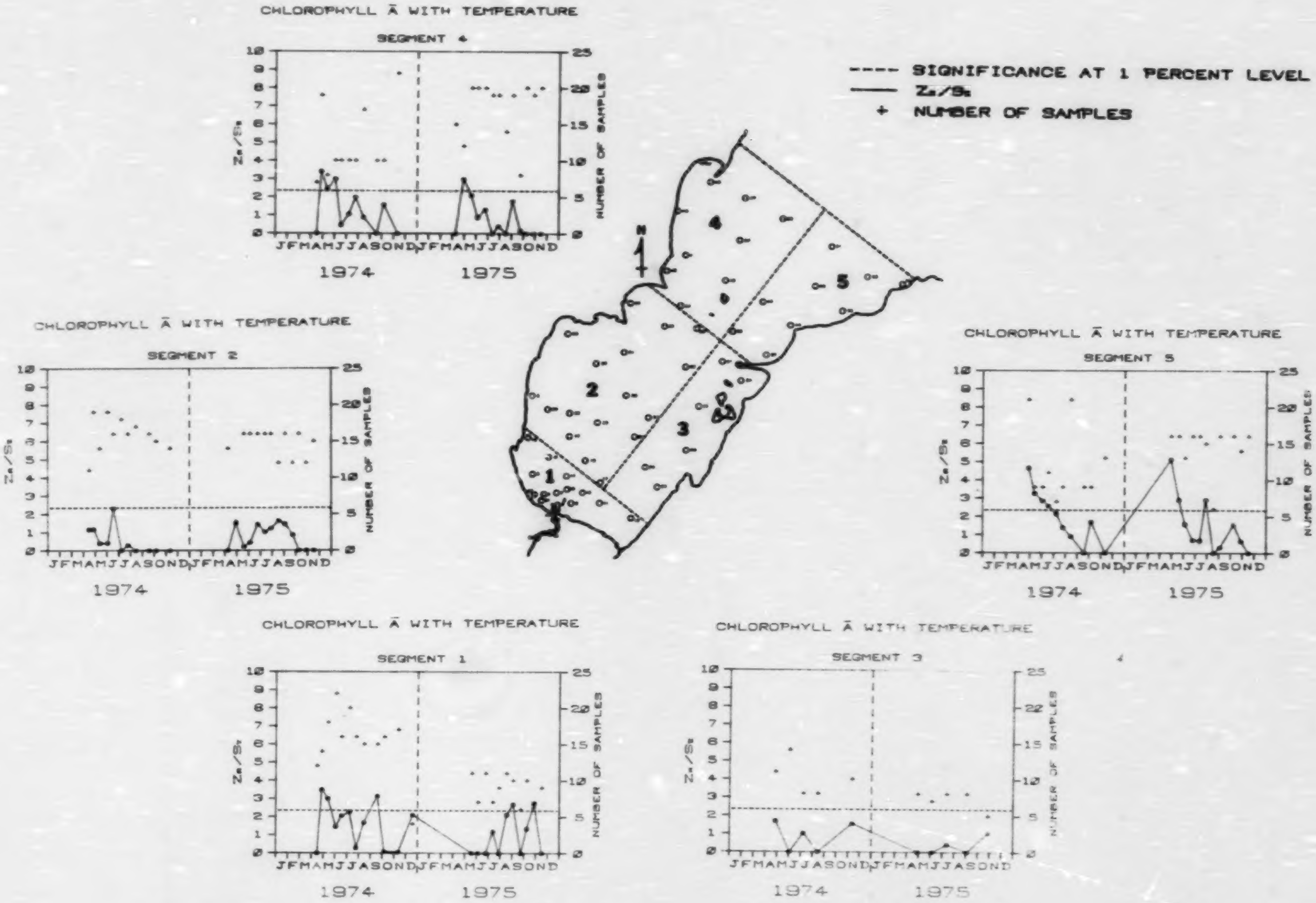


Figure 49. Plot of correlation coefficients (Zr/Sz) of non-filterable chlorophyll *a* with temperature. Dotted line, 99% significance level.

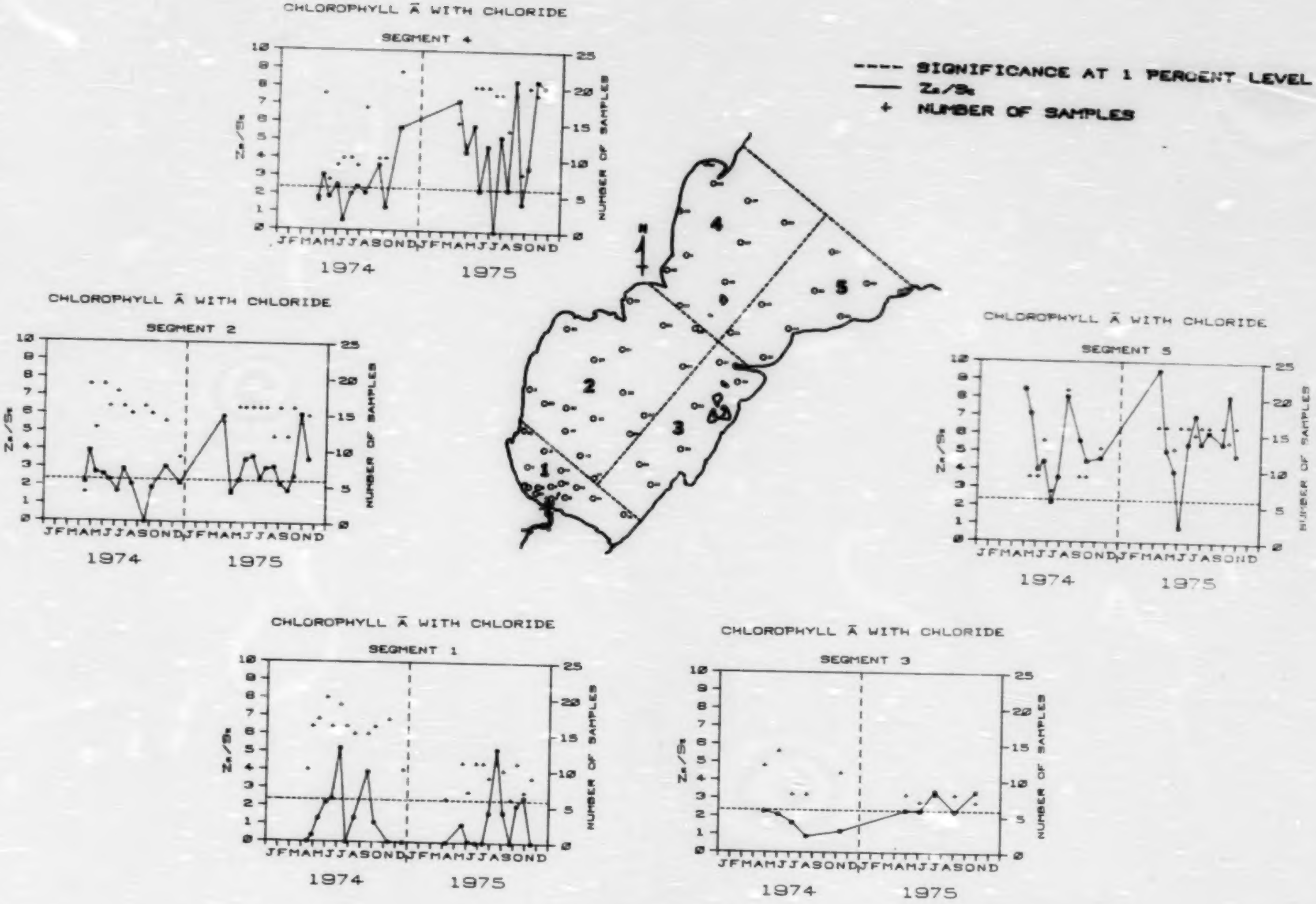


Figure 50. Plot of correlation coefficients (Zr/Sz) of non-filterable chlorophyll *a* with filtered chloride. Dotted line, 99% significance level.

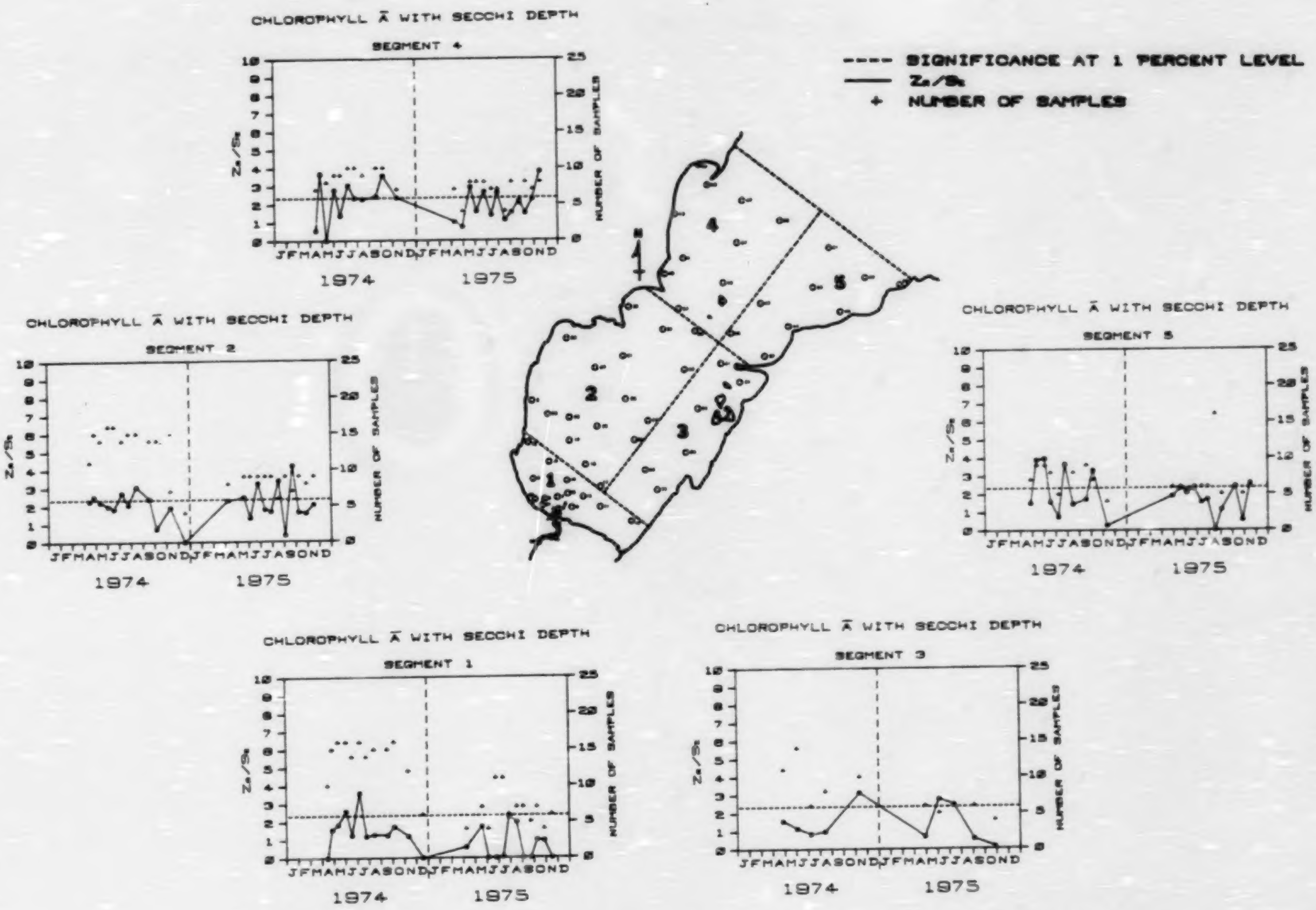


Figure 51. Plot of correlation coefficients (Zr/Sz) of non-filterable chlorophyll *a* with Secchi disc depth. Dotted line, 99% significance level.

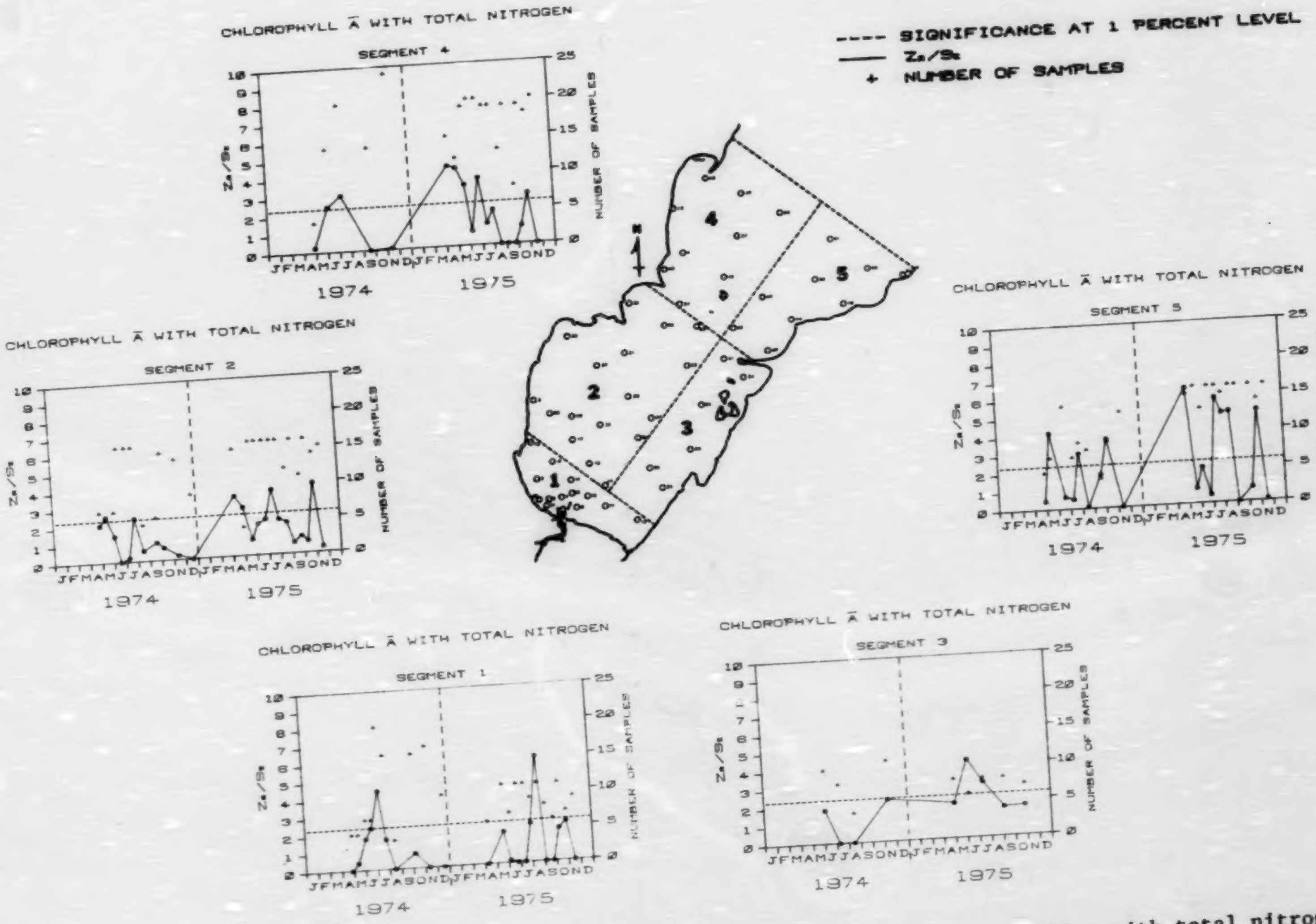


Figure 52. Plot of correlation coefficients (Zr/Sz) of non-filterable chlorophyll a with total nitrogen. Dotted line, 99% significance level.

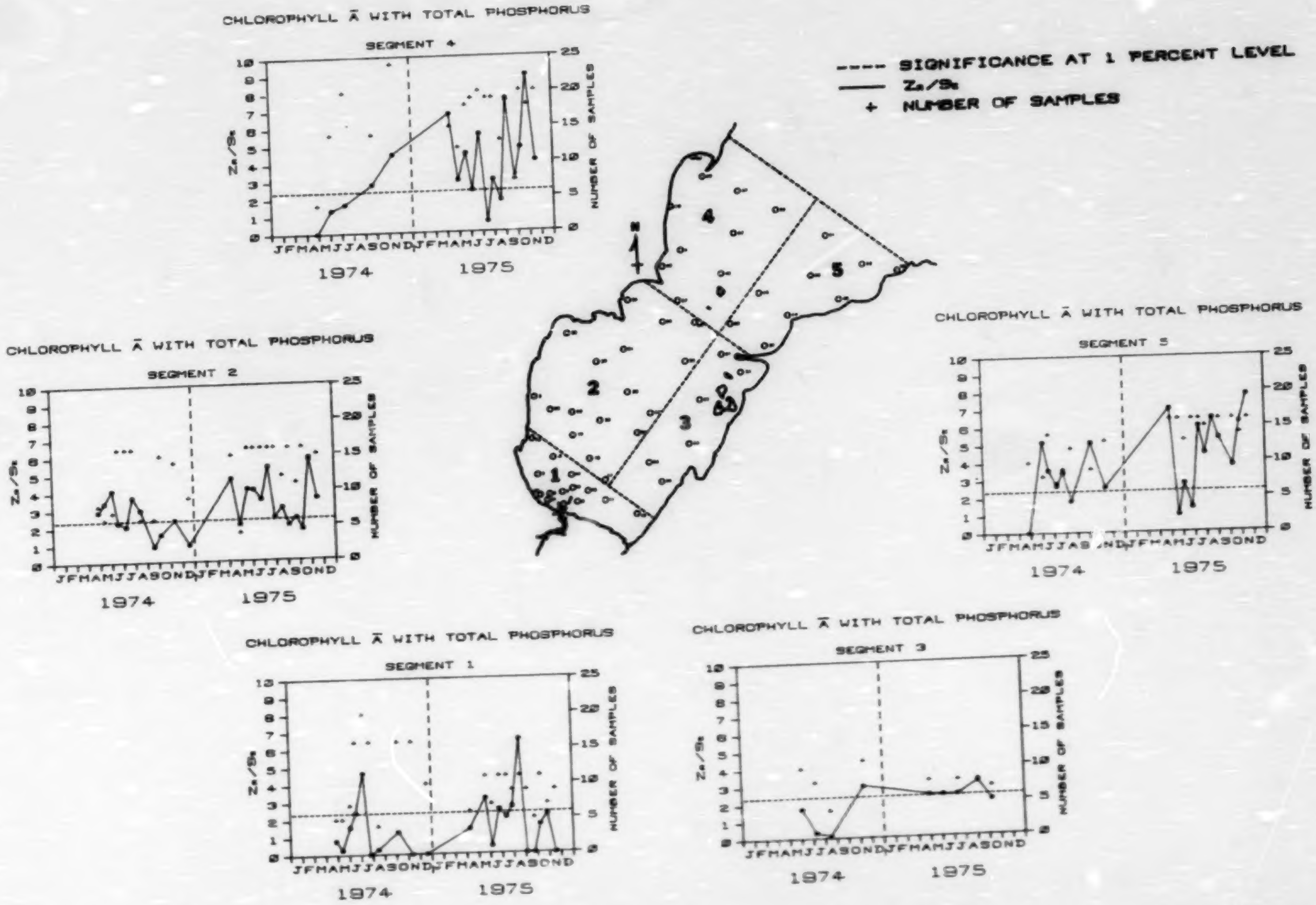


Figure 53. Plot of correlation coefficients (Zr/Sz) of non-filterable chlorophyll *a* with unfiltered total phosphorus. Dotted line, 99% significance level.

TABLE 40. MULTIPLE REGRESSION ANALYSIS OF 1974 DATA USING NON-FILTERABLE CHLOROPHYLL *a* AS DEPENDENT VARIABLE

		Analysis Of Variance	DF	SS	MS	F
Multiple r	0.654					
r Square	0.428	Regression	3	24748.3	4926.1	37.69*
Standard Error	11.42	Residual	151	19695.6	230.4	

Variables in the Equation

Variable	Regression Coefficient (B)	Standard Error of B	F
Particulate Phosphorus	380.49	37.02	105.6*
F. Reac. Phosphate-P	-160.62	51.14	10.8*
F. Nitrate + Nitrite-N	-11.34	3.97	8.1
Constant	15.76		

*Significant at the 1% level.

TABLE 41. MULTIPLE REGRESSION ANALYSIS OF 1975 DATA USING NON-FILTERABLE CHLOROPHYLL *a* AS DEPENDENT VARIABLE

Multiple r	0.593
r Square	0.352
Standard Error	11.18

Analysis Of Variance	DF	SS	MS	F
Regression	3	9708.0	3236.0	25.9*
Residual	143	17886.5	125.1	

Variables in the Equation

Variable	Regression Coefficient (B)	Standard Error of B	F
Particulate Phosphorus	221.09	37.21	35.30*
F. Reac. Phosphate-P	-83.07	41.93	3.92*
F. Nitrate + Nitrite-N	2.78	1.92	2.10
Constant	8.71		

*Significant at the 1% level.

TABLE 42. MULTIPLE REGRESSION ANALYSIS BY SEGMENTS USING NON-FILTERABLE CHLOROPHYLL *a* AS DEPENDENT VARIABLE

YEAR	SEGMENT	MULTIPLE r	MOST IMPORTANT INDEPENDENT VARIABLE		
			1st	2nd	3rd
1974	1	0.846*	part. P	f. inorg. N	tot. N
	2	0.779*	part. P	f. inorg. N	f. reac. PO_4- P
	3	0.257	f. reac. PO_4-P	f. org. P	tot. N
	4	0.888*	u. tot. P	f. org. P	f. inorg. N
	5	0.934*	f. inorg. N	tot. N	f. reac. PO_4-P
1975	1	0.713*	part. P	tot. N	f. inorg. N
	2	0.840*	u. tot. P	f. inorg. N	f. org. P
	3	0.915*	u. tot. P	f. inorg. N	part. P
	4	0.814*	u. tot. P	part. P	f. inorg. N
	5	0.965*	u. tot. P	f. org. P	f. tot. P

*Significant at 99% level

tended to supplement mapping of nutrient distributions based on conventional sampling from ships. Data from the bi-weekly cruises, which were scheduled to coincide with Landsat passes over Saginaw Bay, were correlated with reflectance measurements recorded by satellite sensors in four regions of the visible to near-infrared spectrum. This approach was designed to show empirical relationships between remote and direct measurements that could be used to predict values in unsampled areas.

The satellite data that Bendix chose to process were recorded on two occasions, June 3, 1974 and July 31, 1975, coinciding with cruises 8 and 25, respectively (Table 43). In applying a step-wise linear regression analysis to the data, the water quality measurements were each considered as dependent variables; Landsat reflectance measurements were regressed against these as independent variables. The results indicate which sensor band, band ratio or combination of bands is most useful for predicting levels of each water quality parameter. Correlation coefficients and prediction accuracy were evaluated in each case. The processed Landsat data were used finally to generate a color-coded image or map of water quality categories throughout the bay. Examples are shown in Figures 54 and 55.

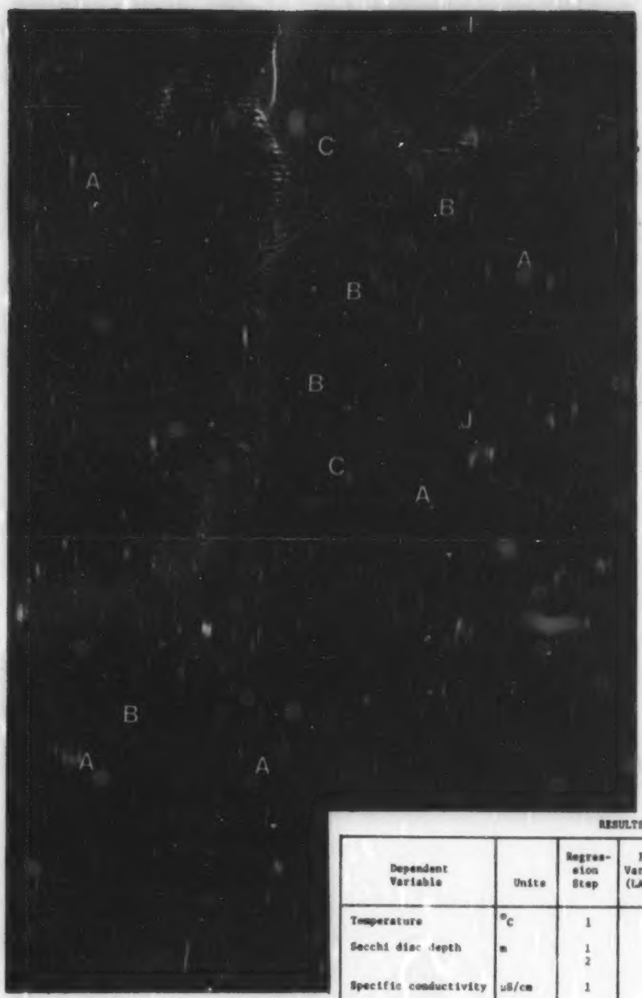
Results of the Bendix study suggest that such water quality maps based on calibrated satellite data can be used with fair reliability to estimate ranges of concentration for certain parameters, even for those variables (e.g., total phosphorus, chloride) which are not directly detectable by remote sensors. This is true because water masses with a varying content of Saginaw River water are enriched correspondingly with nutrients and salts. The same river water is characterized also by its color and particle content, which are markedly different from those of Lake Huron water. As a result, river water in various stages of dilution can be identified by visible characteristics which are correlated with other conservative but invisible features of water quality.

However, the relationships between turbidity and other variables, such as chloride or temperature, are strictly empirical and are subject to change, perhaps even on a daily basis. Moreover, the Landsat data, even on apparently clear days, are subject to atmospheric effects that may vary in each spectral band. In summary, it is apparent that regular Landsat mapping of water quality in the bay is feasible with the following provisions: that sampling is conducted within a few hours of Landsat passage; that such concurrent measurements are used to "re-calibrate" the satellite data on each occasion; that the errors of estimation for each parameter (based on comparison of actual and predicted values) are within acceptable limits. The advantages of using Landsat monitoring as an adjunct to conventional point-sampling are that it provides an economical basis for extrapolating water quality parameters from point samples to unsampled areas, and it provides a synoptic view of water mass boundaries that no reasonable amount of point sampling could duplicate.

The methodologies, results and conclusions of this study are discussed in more detail elsewhere (Rogers, *et al.*, 1975a; Rogers, *et al.*, 1975b; Rogers, *et al.*, 1976).

TABLE 43. CONCURRENT WATER QUALITY AND LANDSAT DATA FOR SAGINAW BAY

	On Site Measurements					Laboratory Analysis								Computer Processing of CCTs				
							Major Metals				Nutrients			LANDSAT Digital Data				
														mean reflectance for station area				
	sta. no.	temp.	Secchi depth	sp. cond.	f. Cl.	nf. chl. a	Na	K	Mg	Ca	f. tot. P	u. Kjel. N	u. tot. P	Bands: 4	5	6	7	no. of pixels to sta. area
		°C	m	µS/cm	mg/1	µg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	Max:254	254	254	252	
JUNE 3, 1974	7	26.1	1.9	243.	10.9	20.70						0.37	0.012	40.6	27.5	14.8	1.4	56
	8	26.7	1.6	258.	11.1	9.38						0.41	0.017	44.0	29.5	16.3	1.5	63
	12	26.8	1.3	277.	18.8	10.70						0.65	0.027	42.8	29.5	16.2	1.7	72
	18	23.6	2.0	237.	9.8	5.61						0.38	0.012	38.1	24.7	13.8	0.5	72
	26	26.0	1.6	251.	13.8	11.60						0.35	0.018	42.7	28.3	14.7	0.4	64
	27	23.7	2.0	239.	10.1	7.38						0.29	0.012	38.1	24.5	12.2	0.3	90
	32	24.8	1.8	235.	10.1	7.38						0.33	0.010	37.2	23.2	11.7	0.1	100
	34	26.9	10.6	294.	24.1	68.50						1.00	0.039	38.6	29.1	16.4	0.9	100
	38	25.1	1.4	244.	11.7	13.60						0.29	0.014	40.4	26.1	12.3	0.1	121
	42	20.4	5.5	211.	6.6	1.84						0.14	0.002	32.3	20.3	9.8	0.3	72
	43	23.5	1.5	246.	12.1	15.60						0.42	0.013	36.0	23.1	10.9	0.2	72
	44	24.4	1.0	281.	20.1	37.10						0.72	0.027	35.6	25.5	14.5	0.8	72
	52	21.5	2.1	238.	10.4	10.00						0.33	0.009	32.3	21.1	11.0	0.4	72
	56	23.7	2.2	244.	10.6	6.58						0.26	0.014	39.5	25.2	12.8	0.6	72
	60	22.5	5.0	215.	6.9	1.84						0.17	0.004	34.0	21.0	10.1	0.1	110
	61	25.7	1.2	252.	12.7	18.00						0.42	0.020	43.7	28.7	14.1	0.6	99
	Mean	24.46	2.0	247.8	12.5	15.36						0.41	0.016	38.5	25.4	13.2	0.6	81.7
	Std.Dev.	1.92	1.3	21.8	4.7	16.53						0.22	0.009	3.8	3.1	2.2	0.5	
JULY 31, 1975	1	19.8	0.3	772.	1118.	36.20	41.	5.3	19.	101.	0.054	0.81	0.200	50.2	38.0	23.8	6.8	10
	2	17.5	1.0	320.	200.	17.00	10.	1.7	10.	44.	0.010	0.27	0.029	47.0	27.2	14.2	3.2	49
	3	19.2	0.6	330.	207.	3.74	11.	1.8	11.	50.				62.8	42.0	18.6	4.3	56
	5	18.0	0.6	492.	485.	59.70	20.	2.9	16.	70.				43.6	27.4	17.1	4.7	81
	6	18.7	0.4	828.		27.90	42.	5.2	19.	104.	0.070	0.52	0.145	46.1	32.3	19.6	4.3	81
	7	17.0	0.6	425.	364.	50.80								43.1	25.8	15.3	2.7	90
	9	19.0	0.3	827.	1070.	38.20								46.5	32.5	19.9	4.1	27
	10	18.0	0.7	381.	287.	53.90	12.	2.1	13.	55.				42.8	25.3	15.0	3.6	67
	14	18.4	0.8	309.	196.	29.00								45.1	27.4	14.0	2.9	63
	15	17.0	1.3	323.	160.	6.17	7.	1.2	9.	39.				46.7	25.8	13.0	2.8	42
	16	18.2	0.8	315.	190.	12.10	9.	1.7	10.	46.				56.9	37.2	17.5	4.2	49
	18	17.7	1.3	293.	170.	9.46	9.	1.5	10.	45.	0.006	0.19	0.029	47.0	26.3	12.8	2.7	56
	19	16.2	1.7	303.	157.	2.73								45.9	25.0	12.5	2.8	72
	20	17.5	1.5	268.	159.	5.93					0.004	0.24	0.016	45.8	23.5	12.4	2.4	49
	21	17.8	0.5	466.	465.	69.30								44.9	29.5	18.5	5.0	72
	22	16.3	1.4	283.	163.	4.41								44.1	23.1	11.3	2.3	42
	23	17.0	1.7	286.	172.	5.93								44.1	23.4	11.9	3.1	64
	28	15.4	1.7	329.	194.	5.85								43.6	23.7	11.6	3.0	64
	29	16.6	1.8	269.	140.	5.69					0.010	0.23	0.014	43.5	22.7	11.3	2.2	42
	30	18.7	1.2	285.	153.	6.74	8.	1.5	10.	42.				52.5	29.1	15.8	5.4	64
	31	16.2	2.2	274.	137.	3.93								43.5	22.2	11.5	2.2	49
	35	15.8	2.2	283.	147.	5.13					0.004	0.20	0.018	44.8	23.8	13.4	4.7	80
	36	17.8	1.8	262.	124.	6.17								48.2	27.1	16.3	5.7	64
	41	18.8	0.4	764.	950.	55.50					0.043	1.00	0.185	46.8	32.1	21.9	7.1	17
	54	19.0	0.3	736.	882.	26.80					0.071	0.94	0.213	53.0	40.7	27.2	9.0	8
	55	19.2	0.3	659.	759.	22.80	33.	4.0	19.	93.	0.071	0.73	0.196	53.7	41.3	27.3	8.3	12
	59	18.0	0.8	359.	265.	36.60	12.	2.1	12.	52.				46.8	29.5	16.7	3.9	64
	Mean	17.73	1.04	423.7	358.2	22.507	17.83	2.58	13.17	61.75	0.0343	0.513	0.1045	47.37	29.03	16.31	4.20	
	Std.Dev.	1.15	0.62	196.0	316.6	20.651	13.15	1.45	3.97	24.12	0.0303	0.328	0.0896	4.73	6.03	4.61	1.85	



Code	Secchi Depth (meters)
A	0.3
B	0.6
C	0.8
D	1.0
E	1.3
F	1.5
G	1.7 to 1.8
H	2.2
I	3 to 3.3
J	Uncategorized

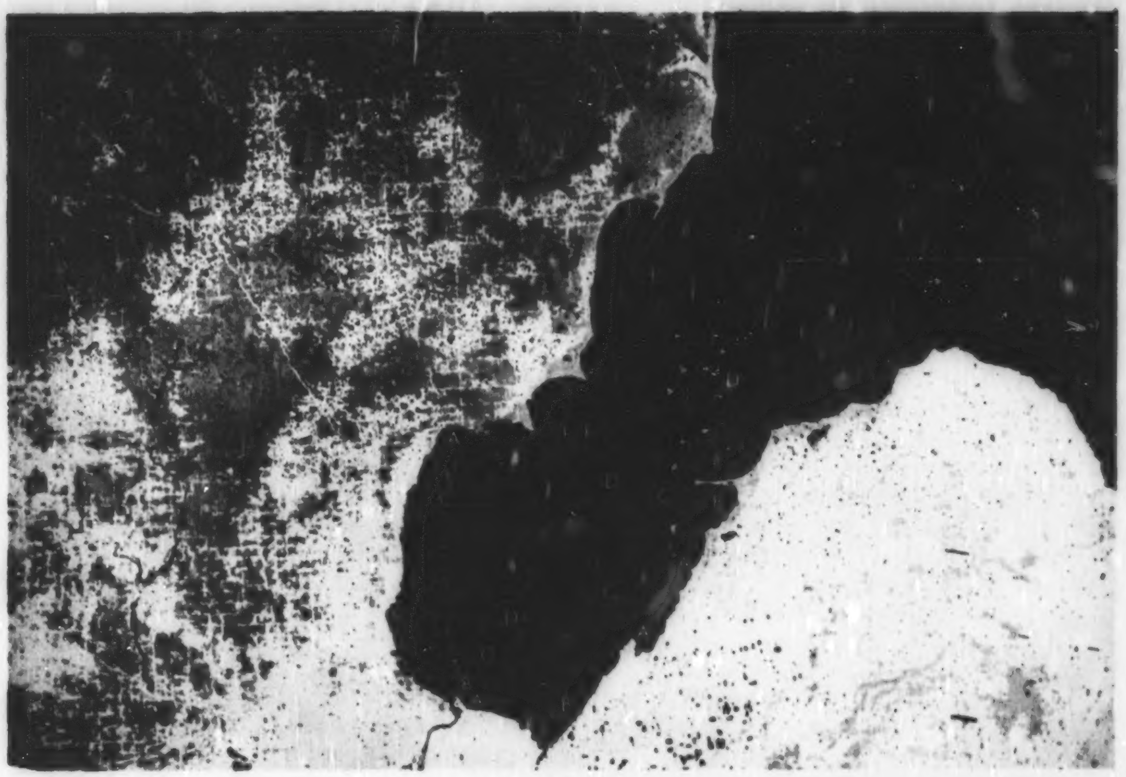
Map covers area approximately 25 by 40 nautical miles.

Image produced by
Bendix Aerospace
Systems Division

RESULTS OF STEPWISE REGRESSION ANALYSIS

Dependent Variable	Units	Regression Step	Independent Variable Added (LANDSAT Band)	Regression Variables (LANDSAT Bands)	Standard Error of Estimate	Percent Inaccuracy	Regression Correlation Coefficient
Temperature	°C	1	5	5	0.6759	3.8	0.819
Secchi disc depth	m	1 2	6 7	6 6,7	0.3839 0.2890	36.9 27.7	0.791 0.892
Specific conductivity	µS/cm	1	6	6	115.130	27.2	0.817
Filtered Chloride	mg Cl/ℓ	1	6	6	180.378	30.4	0.829
Non-filterable chlorophyll *a*	µg chl. *a*/ℓ	1 2	6 4	6 6,4	18.713 14.905	83.2 66.2	0.450 0.721
Unfiltered sodium	mg Na/ℓ	1	6	6	8.5521	48.0	0.785
Unfiltered Potassium	mg K/ℓ	1 2	6 4	6 6,4	0.9698 0.7737	37.6 30.0	0.772 0.876
Unfiltered magnesium	mg Mg/ℓ	1 2	6 4	6 6,4	2.4170 1.4331	18.4 10.9	0.815 0.945
Unfiltered calcium	mg Ca/ℓ	1 2	6 4	6 6,4	14.9092 11.0980	24.1 18.0	0.808 0.909
Filtered total phosphorus	mg P/ℓ	1	6	6	0.0121	35.3	0.926
Unfiltered Kjeldahl nitrogen	mg N/ℓ	1	6	6	0.1429	27.9	0.912
Unfiltered total phosphorus	mg P/ℓ	1 2	6 4	6 6,4	0.0225 0.0155	21.5 14.8	0.972 0.988

Figure 54. Categorized Landsat image-map of water transparency on June 3, 1974 (original in color).



	A	B	C	D	E	Standard Error of Estimate
Temperature (°C)	31.6*	27.3	25.2	23.3	20.6	1.6
Secchi Depth (m)	<0.4*	0.4	1.9	2.7	3.9	1.1
Chloride (mg/ℓ)	37.5*	19.7	10.4	9.9	8.2	1.9
Conductivity (micromhos)	363*	284	243	235	221	8.9
Total Kjeldahl Nitrogen (mg/ℓ)	1.55*	.71	.28	.27	.22	.08
Total Phosphorus (mg/ℓ)	.066*	.032	.014	.012	.005	.004
Chlorophyll *a* (µg/ℓ)	99.1*	37.5	5.0	7.6	7.6	8.5
Total Solids (mg/ℓ)	290*	217	179	174	164	15
Suspended Solids (mg/ℓ)	17.6*	8.1	3.2	2.7	1.6	2.2

*Values are beyond the range of sample data and may not occur in nature.

Image produced by Bendix Aerospace Systems Division.

Figure 55. Categorized Landsat image-map of water quality variables on July 31, 1975 (original in color).

SECTION 8

EVALUATION AND DISCUSSION

WATER QUALITY VARIATIONS

The following discussion, by parameter, deals with the data presented in Tables 6-38 and Figures 4-48. The results are considered, first, from the standpoint of six key parameters (temperature, chloride, Secchi depth, chlorophyll *a*, Kjeldahl nitrogen and total phosphorus monitored at six stations. The latter were chosen to represent two years of sampling on the bay and Saginaw River. Data for one meter depth and near the bottom show the occurrence of stratification as well as seasonal variability at each point. Diurnal variations at station 56 are also represented for six occasions during 1975.

Secondly, all of the results are considered in terms of spatial (segment and total bay) and temporal (quarterly and annual) averages. These segments, established for modeling purposes, represent areas of generally distinctive water quality (Richardson and Bierman, 1976). Some statistical differences between the 1974 and 1975 data sets may have resulted from the sampling of fewer stations in each segment during 1975. However, the station sub-sets sampled in 1975 were those which, on statistical analysis of the 1974 results, were found to best represent average water quality in each of the segments.

Temperature

Annual mean temperatures were highest in relatively stagnant inshore waters of the inner bay (Sta. 34) and lowest where Lake Huron waters usually intrude along the northern side of the bay mouth (Sta. 49). In most areas two temperature maxima occurred in July and in August (Figure 14). Water temperatures rose earlier during spring 1975 and were generally warmer all year (Table 7).

Evidence of thermal stratification is seen in the comparison of surface (1 m) and bottom waters in Figure 14. A thermocline occurred in the inner bay during calm periods, chiefly in May. Generally, however, a combination of wind and wave action caused complete mixing in all but protected or deeper areas. In the outer bay a thermocline persisted at the 15 - 20 m level throughout the May - October period.

Annual mean temperature by segment decreased in order of segments 1, 3, 2, 5 and 4. This pattern shows that the dominant influx of cooler Lake Huron water is along the northwestern side of the bay. Consequently, the outflow of bay water is mainly along the southeastern side. As expected, the strongest thermal gradients and barriers occurred in the transitional zone toward the western side of the mid-bay area. These often corresponded with turbidity and chemical boundaries, as subsequent data show.

Occasional instances of thermal inversion were noted near the Saginaw River mouth when warmer but denser, chloride-rich water lay near the bottom. For some stations, temperature means at measured depth are biased toward higher values because only surface (1 m) waters were sampled by helicopter during midwinter (i.e., Sta. 34, Table 6).

Studies by Consumers Power Company (cited in Freedman, 1974) have shown that thermal discharges from their plant at the Saginaw River mouth have been detectible for some 2 miles offshore. Although no such effects were noted in the present survey, Landsat (satellite) imagery recorded during winter (1975) shows a persistent area of open water adjacent to the plant (Figure 4).

Oxygen, dissolved (d. O_2)

In general dissolved oxygen remained at near-saturation levels year-round throughout the bay. Thus, the observed ranges in dissolved oxygen content were mainly a function of water temperature variations. The lowest mean value (i.e., 6.7 mg O_2/ℓ at Sta. 55) show some tendency toward oxygen depletion in the lower Saginaw River. There, the lowest single value, recorded at 6 m, was 3.3 mg O_2/ℓ. Otherwise, unusually high oxygen levels in the inner bay were noted only occasionally, as in July 1975 during a calm period which accompanied a heavy algal bloom. At that time, d. O_2 values at Station 8, for example, were 13.5 mg O_2/ℓ and 8.4 mg O_2/ℓ at 1 m and 3 m, respectively. The latter value represents the saturation level of d. O_2 at ambient temperature, while the former represents super-saturation due to phytoplankton photosynthesis.

Three d. O_2 values were recorded through the ice in the inner bay during February 18-19, 1975:

Station	mg d. O_2/ℓ	Temperature	% Saturation
3	12.0	1.0	86.8
16	11.2	.8	81.2
26	4.4	1.2	31.9

The minimum value of 4.4 mg O_2/ℓ was from station 26 near the Sebewaing River mouth. The other two are from similar nearshore areas on the opposite side of the bay.

Specific Conductivity (sp. cond.)

Extremes of conductivity were measured in the Saginaw River (highest) and in the outer bay (lowest) toward the western shore. By far the greatest fluctuations in conductivity occurred in segment 1, the area most affected by river inputs of salts and nutrients. Segment 1 was much less subject to conductivity variations in 1975 than in 1974. Throughout the bay conductivity varied most during the spring and summer quarters. Like chloride, conductivity serves generally as a label for the component of Saginaw River water that occurs in any part of the bay. However, conductivity is less conservative since it is affected by ions, other than chloride, that are biologically active.

Chloride, filtered (f. Cl)

Mean concentrations of chloride were highest in the Saginaw River (Sta. 54) and lowest in the extreme outer bay (Sta. 50). Chloride values were consistently much higher and more variable in the inner bay (Seg. 1-3). The variations were particularly large along the entire western half of the bay where, apparently, there is more frequent mixing of Lake Huron and bay water during the spring. At outer bay stations 49 and 51 occasional higher chloride values at the surface indicate layering of bay waters over colder Lake Huron water. This is confirmed by temperature (Table 6). These "peaks" of surface chloride concentration in the outer bay, that occurred during the May - July period, may result from periodic wind stress (mainly southwesterly) on surface waters of the inner bay. Within the inner bay, chloride values fluctuated without any such clear pattern.

pH

Variations in mean pH were relatively small among bay segments. Individual values ranged from 6.9 to 9.4, with most of the lower levels occurring in the Saginaw River and river mouth, and in Lake Huron waters in the outer bay (e.g., Sta. 49, 50). Occasionally, a high pH (>9) was recorded in surface waters during phytoplankton blooms, when dissolved CO_2 may have been depleted by photosynthesis. Such an effect was seen, for example, at several inshore stations of the inner bay during July 13-16, 1975*. In most cases the pH of underlying (poorly-lighted) water was several tenths lower. Presumably the lower (<8) mean pH of Saginaw River water results either from acidic pollutants and/or additional CO_2 generated by organic decay.

Alkalinity, total (tot. alk.)

Alkalinity values were relatively high (ca. 180 mg $CaCO_3/\ell$) in the Saginaw River and lowest (ca. 80 mg $CaCO_3/\ell$) in the extreme outer bay. Between these extremes the distribution of alkalinity generally followed that of Saginaw River water throughout the bay. This is evidenced by the positive correlation (based on regression analysis) of alkalinity and chloride values, particularly within the inner bay. Freedman (1974) noted that slightly higher alkalinity values in the summer hypolimnion, as reported in Lake Survey data (1966), may result from sinking and re-solution of precipitated $CaCO_3$. However, there was no such clear evidence of vertical variations in alkalinity in the present data. Throughout the bay alkalinity values were generally highest and most variable during the spring quarter.

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*The eastern side, and in particular Station 26, showed high pH values during May - July in 1974 and 1975.

Secchi Disc Depth

Mean Secchi depth values were lowest, indicating extreme turbidity, in the Saginaw River (Sta. 55) and highest in the mid-outer bay (Sta. 51). In the river water clarity was lowest during the May - August period, but with only minor fluctuations. This indicates a continuously high loading of pariculate matter. In the inner bay (Seg. 1, 2, 3) greater clarity and more variation occurred. An exception was Station 34 in Wildfowl Bay which, because of its protected status and low clarity, resembled the river stations. Much higher mean values and variability were seen in the outer bay, particularly in segment 5.

It is apparent from Figure 24 that there is considerable overlap in the ranges of Secchi depth between the inner and outer bay. This and the great variations of clarity that occurred in the outer bay indicate that active mixing of clear (Lake Huron) and turbid (bay) water takes place there. Such intermittant mixing (cf; Fig. 23) may occur mainly as a function of wind-generated circulation. Sharp turbidity boundaries were observed frequently in segments 4 and 5 where greatly different water masses were in contact.

In the inner bay, however, clarity variations probably were affected to a greater extent by wave-resuspension of sediments in shallow water as well as by the mixing of river and bay water. Turbidity boundaries were much less evident in this area. Where available, first quarter data (Fig. 24, seg. 1, 3) show that water clarity under ice cover is significantly greater.

Chlorophyll *a*, non-filterable (nf. chl. *a*)

Concentrations of particulate chlorophyll *a* were higher in the inner bay (seg. 1) than in the outer bay (seg. 4) by a factor of 10. Variability was also high in segment 1, the upper extreme being approximately 20-fold greater than the lower. Mean values in the Saginaw River were considerably lower (by 1/3) than those in segment 1, possibly due to extreme turbidity and other pollution in the river. When the water column was stratified, chlorophyll levels were usually higher near the surface. However, the 1 meter mean values in Table 16 (except for Sta. 55) are biased downward by mid-winter samples of low chlorophyll content. Otherwise, this table shows that chlorophyll *a* on the western side of the inner bay (seg. 2) is markedly less abundant than on the eastern side (seg. 3) where there is less influx of Lake Huron water.

Temporal variations of chlorophyll *a* followed a reverse pattern to that of turbidity (i.e., Secchi depth). The amount of chlorophyll variation was smallest in the outer bay and greatest in the river. The opposite was true of Secchi depth. This indicates that extreme variations in the particle content of bay water need not represent similar changes in the crop of algal chlorophyll. In short, much of the particulate matter is probably not algal in nature.

Mean values by segment were generally highest in the third quarter. Wide ranges of chlorophyll concentration, especially in the inner bay, indicated the occurrence of algal blooms. In fact, such blooms were observed frequently during the growing season.

Carbon, unfiltered organic (u. org. C)

Extreme levels of u. org. carbon were highest in the Saginaw River (Sta. 55) and lowest in the outer bay (Sta. 57). Segment means followed a similar pattern, ranging from lowest in segment 4 to double that value in segment 1. In segment 1 the greatest variations also occurred during the spring (2nd) quarter in 1974, but not in 1975. No first or third quarter data were obtained for 1974 due to experimental problems. However, the complete data set for 1975 indicated a u. org. C peak occurring in all segments during the summer (3rd) quarter. That is consistent with the observed peak in chlorophyll *a* during the same period. The next highest segment means in 1975 were in the second quarter in all areas except for segment 3 where winter (1st) quarter values were relatively higher. It is interesting to note that, although chlorophyll *a* levels were not unusual at that time, high u. Kjel. N and low d. O_2 values (even relative to segment 1) suggest a significant winter input of organic matter to segment 3. A possible source is the Michigan Sugar Company beet processing plant on the Sebewaing River.

Carbon, filtered organic (f. org. C)

Concentrations of f. org. carbon followed similar distributional and seasonal patterns as those of u. org. C. With regard to 1975 segment means, the u./f. org. C ratios ranged from 1.34 in segment 3 to 1.09 in segment 4. This suggests again that loadings of particulate carbon were relatively high in the Sebewaing area, particularly during mid-winter. The range of f. org. C values was on the whole less than that of u. org. C, especially in the outer bay (seg. 4 and 5). This indicates a wider fluctuation of particulate carbon levels, including cellular biomass, than of dissolved and colloidal forms. A similar relationship was seen between particulate (unfiltered minus filtered) and dissolved forms of nitrogen (Figs. 34 and 39).

Solids, unfiltered total (u. tot. sol.)

Concentrations of u. tot. solids were predictably highest in the Saginaw River (Sta. 55) and lowest in the extreme outer bay (Sta. 50). Although sampling coverage was incomplete and mainly limited to 1975, the data indicate that u. tot. solids levels in the inner bay were approximately 2-fold higher than in the outer bay. Quarterly mean values were fairly constant within each segment, suggesting that observed summer increases of non-filterable chlorophyll occurred at the expense of dissolved solutes and colloids in the water column.

Silicate-silicon, filtered reactive (f. reac. SiO_2-Si)

Extreme values of f. reac. silicates were highest in the Saginaw River (Sta. 54) and lowest in the mid-bay area (Sta. 60). However, the segment means were highest in the outer bay (seg. 4) and lowest in the eastern inner bay (seg. 3). The greatest variability occurred in segment 1. This distribution suggests that inputs to the bay of silicate-rich water come intermittently from the Saginaw River and more regularly from Lake Huron. Dissolved silicate is probably depleted within the inner bay due to heavy diatom growth in these eutrophic waters. The data in Figure 32 show, in fact, that silicate depletion in the inner bay (seg. 1, 2, 3) was generally strongest during the spring and fall quarters when active diatom growth occurs. In the low-productivity waters of Lake Huron (i.e., seg. 4), this effect is not noticeable.

Ammonia-nitrogen, filtered total (f. tot. NH_3-N)

Ammonia, like dissolved oxygen, is subject to diffusion and biological uptake and therefore is a highly labile feature of water quality. Data in Figure 33 indicate the variable nature of ammonia values during 1974, even in the outer bay.

Levels of dissolved ammonia, which results mainly from organic decay, were highly variable throughout Saginaw Bay during 1974 (Figure 33). This appears to be real since in segment 1, at least, variability was great during both years. The highest mean values were in the Saginaw River and in segment 1. Mean values for all segments were generally highest in the summer (3rd) quarter during 1974 and in the winter (1st) quarter during 1975. This suggests that generation of ammonia by decay and biological uptake of ammonia were dominant respectively in 1974 and 1975. However, the reasons for this difference in 1974 and 1975 levels are not clear.

Nitrate + nitrite-nitrogen, filtered (f. NO_3 + NO_2-N)

Extreme values of f. nitrate + nitrite occurred in the Saginaw River, Station 55 (highest) and the western inner bay, Station 50 (lowest). The segment means are more informative, showing a narrow range from 0.200 to 0.498 mg N/ℓ in segments 2 and 3, respectively. From the Figure 34 data it is obvious that inputs of nitrate + nitrite from the Saginaw River to segment 1 during 1974 were very high in the first quarter (1.824 mg N/ℓ) and declined to a low of 0.090 mg N/ℓ during the third quarter. This pattern diminished progressively toward the outer bay (seg. 4), and was less pronounced altogether during 1975. This seasonal decline of nitrate + nitrite levels was likely due to a combination of decreasing input rates (after the spring runoff) and increasing consumption by phytoplankton as the growing season advanced.

Nitrogen, unfiltered Kjeldahl (u. Kjel. N)

Total Kjeldahl nitrogen values ranged from a high of 1.293 mg N/ℓ in the Saginaw River to the low of 0.155 mg N/ℓ in the outer bay (Sta. 50). Segment means also show the high and low values in segments 1 and 4, respectively, In all segments during 1974, u. Kjel. nitrogen values rose from a relatively low level in winter-spring (quarters 1 and 2) to a maximum in summer, followed by a decline to an intermediate fall value (quarter 4). In 1975, the pattern was similar but less definite. Variability also was highest during the spring in segment 1; but in segments 2 and 4 it was highest in the fall, perhaps due to increased wind-induced mixing of inner bay and Lake Huron water coupled with the fall overturn.

The relative increase in Kjel. nitrogen from the second to the third quarter was accompanied by decreases in total phosphorus (Fig. 43) and conservative factors, such as chloride (Fig. 19). The latter changes are a function of decreasing inputs via the Saginaw River, but the Kjel. N increase over this interval was possibly due to nitrogen fixation by the abundant crops of blue-green algae observed during the summer. Concurrent changes in chlorophyll *a* concentration (Fig. 26) closely parallel those of u. Kjel. N.

Nitrogen, total (tot. N)

These values were calculated for most samples by simple addition of f. nitrate + nitrite-N and u. Kjeldahl N measurements in order to furnish a counterpart for unfiltered total phosphorus data.

Extreme levels of tot. nitrogen were highest in the Saginaw River (Sta. 54) and lowest in the outer bay (Sta. 50). Segment means varied only 2-fold from the low in segment 4 to the high in segment 1. Variability of tot. N was on the whole greater during 1975 in segments 1, 3 and 5, especially in the winter and spring quarters.

Segment means show a general decline of tot. N from spring to fall, suggesting a steady depletion of all forms of nitrogen after initial high inputs from the Saginaw River in early spring. This pattern is also evident but less obvious in the outer bay (seg. 4 and 5).

The data in Table 28 do not suggest any consistent differences between tot. N values at 1 m and near the bottom.

Phosphate-phosphorus, filtered reactive (f. reac. PO_4-P)

Levels of f. reac. phosphates ("ortho-phosphates") were highest in the Saginaw River (Sta. 45) and lowest in mid-bay (Sta. 60). Segment means ranged from near-detection limits over most of the bay to a high of 0.011 mg P/ℓ in segment 1. Although these mean values were low and relatively uniform throughout the year, periodic higher levels during the 2nd quarter are indicated by the much greater range of values then, particularly in the inner bay (Fig. 40). On the western side (seg. 2 and 4) the greater range occurred during the 3rd quarter. These periodic high levels appear to have been much less prominant during 1975. This may reflect a difference in the volume or quality of spring inputs of phosphates between 1974 and 1975. However, it is not possible to distinguish between the effects of inputs, losses and phytoplankton uptake in interpreting these PO_4-P data.

Phosphorus, filtered total (f. tot. P)

The f. tot. phosphorus maximum occurred in the Saginaw River (Sta. 1) and the minimum in the outer bay (Sta. 45). The corresponding high and low segment means were in segments 1 and 4, respectively. Variability was also highest in segment 1 where the quarterly mean values were relatively high, especially during the spring. Quarterly means in all other segments were fairly constant in the 0.002 - 0.010 mg P/ℓ range during both years. The observed ranges of individual values, however, were notably different from segment to segment and year to year. Periodically, high values of f. tot. P were seen (Fig. 41) in the western outer bay (seg. 4), an area that was poorest in f. reac. P and u. tot. P.

Phosphorus, unfiltered total (u. tot. P)

Extreme values of u. tot. phosphorus were highest in the Saginaw River (Sta. 55) and lowest in the outer bay (Sta. 51). The highest and lowest segment means were seen in segments 1 and 4, respectively. In general, u. tot. P inputs from the Saginaw River to segment 1 were highest in the spring quarter (Fig. 43), and diminished through summer and fall. This pattern was progressively weaker toward the outer bay; in segment 4 mean u. tot. P was almost constant throughout the year.

The data in Table 32 suggest that there was no consistent difference between u. tot. P concentrations at 1 meter and near the bottom. In view of the normally high levels of dissolved oxygen throughout the bay, there is no reason to expect that the rate of net phosphorus flux from sediments is unusually high. However, wind stress may cause resuspension of particulate phosphorus in shallow areas and a temporary increase in u. tot. P.

Sodium, unfiltered (u. Na)

Concentrations of sodium were highest in the Saginaw River (Sta. 55) and lowest in the extreme outer bay (Sta. 50). Segment means followed the same pattern, with the high and low occurring in segments 1 and 4, respectively. Variability of sodium levels was by far greatest in segment 1, especially during the spring and fall quarters (2 and 4). This indicates a sizeable input via the Saginaw River during the peak runoff periods (see Fig. 10). Since sodium behaves conservatively, it serves to label river water in the course of its movement and dilution throughout the bay. The distribution of sodium was highly correlated with that of chloride, another conservative factor (Table 39).

Sodium levels were highest during the second quarter in those segments (1, 3 and 5) that seem to be most influenced by the flow of Saginaw River water. In other areas (seg. 2 and 4) more affected by periodic intrusions of Lake Huron water, the sodium level was highest in the first quarter and tapered off gradually throughout the rest of the year. This difference may reflect some weakening of Lake Huron water flows into Saginaw Bay during midwinter, or a correspondingly greater movement of sodium-rich river water into those areas under the ice.

Potassium, unfiltered (u. K)

Extreme levels of potassium were distributed like those of sodium. An important difference is that the annual segment mean for potassium was as high in segment 3 as in segment 1. This indicates a significant input of potassium to segment 3, other than from segment 1, since neither chloride, conductivity nor sodium were conserved to that extent. Potassium and chloride distributions were correlated (r = 0.88) throughout the bay, but less so than sodium and chloride (Table 39). Moreover, potassium levels were highest during the first quarter in segments 1, 2 and 4, but peaked during the second quarter in segment 3 (and possibly segment 5, although only one measurement was available then). Variability was greatest during the second quarter throughout the bay.

Since fertilizers are typically an important source of potassium in runoff from agricultural land, it is possible that such runoff enters the bay every spring from numerous canals which drain the rich farming areas bordering segment 3.

Calcium, unfiltered (u. Ca)

Like sodium and potassium, calcium was most concentrated in the Saginaw River (Sta. 55) and rarest in the outer bay (Sta. 51). Seasonal levels in all segments were highest in the first quarter and declined generally throughout the year. In the inner bay, notably segment 1, variability was greatest during the period of high runoff (quarter 2). Otherwise, the seasonal decline of calcium levels may be related also to decreased solubility of calcium salts (e.g., calcium carbonate) at higher water temperatures, and to biological uptake. Alkalinity values followed a similar pattern, at least within the inner bay. In the outer bay (segments 4 and 5) calcium was more highly correlated in its distribution with chloride than were the other major metals.

Magnesium, unfiltered (u. Mg)

Magnesium concentrations were highest in the Saginaw River (Sta. 55) and lowest in a nearshore area of the outer bay (Sta. 47, seg. 4). However, the highest segment mean was in segment 3, rather than in segment 1. The segment mean for magnesium in segment 1 was slightly lower than that of sodium, but the former values were much higher in the outer bay (segments 4 and 5). This suggests that magnesium levels in the bay are influenced less by inputs from the Saginaw River than those of sodium, potassium or calcium.

The relatively high level of magnesium in segment 3 occurred during the fourth quarter when levels elsewhere in the bay were declining. This points to a significant input from some artificial source, possibly connected with sugar beet processing in the Sebewaing area. Sampling for major metals in segment 3 was confined to Station 26 at the mouth of the Sebewaing River.

WATER QUALITY TRENDS

Periodic surveys of Saginaw Bay waters since 1935 have provided some basis for assessing long-term changes or trends in water quality during the past 40 years. Such trends reflect real changes in the quality of loadings, chiefly from the Saginaw River system. They also reflect, to an uncertain degree, changes in climate, lake levels, and other natural cycles. Furthermore, in comparing data from different surveys, allowances must be made for discrepancies due to different methodologies, station locations and sampling dates. A comparison of all the mean data for 1974 and 1975 (Table 44) shows how much variation might be expected from year to year on a whole bay basis. The climatic and flow data already referred to in Figures 9 and 10, and in Table 7, indicate natural causes for at least some of this variation.

The data show clearly that 1974 was generally a cooler, wetter year than 1975; apparently, enrichment of the bay (via tributaries) and consequent algal production were greater in 1974. There is little reason to suspect that the observed differences relate to a change in human impact on water quality. Rather, it appears to have resulted from a short-term climatic change, and therefore does not constitute a trend.

In our experience, water quality conditions almost anywhere in the bay are subject to great variation on a seasonal or even weekly basis. This is due to the often turbulent nature of the open bay and its estuarine character; i.e., large chemical gradients frequently occur within the space of a few kilometers. These variations, imposed on normal seasonal differences from year to year, complicate the problems of establishing "baseline" water quality and detecting genuine trends. The point is that no two-year survey of Saginaw Bay would be adequate to establish any real trends of water quality such as might result from a gradual change in nutrient loadings; natural yearly variations are manifestly too great.

Over the 40-year time span, more evidence of any long-term changes in the human impact on Saginaw Bay waters should be apparent. Unfortunately, data are scarce for most parameters. In Table 45, data representing three key parameters are compared: chloride (a conservative tracer); chlorophyll *a* (indicating primary production); total phosphorus (a major nutrient). To compensate in part for differences in sampling coverage and timing among surveys, the data have been averaged (or expressed as a range) over comparable portions of the river and bay. The results suggest a trend, at least with regard to the history of chloride and chlorophyll *a* levels.

Chloride concentrations in the Saginaw River during 1935 and 1956 surveys were higher than current values by a factor of 5. This trend is less pronounced in data for the inner bay and diminishes further in the outer bay data. It is noteworthy that inputs of chloride to the Saginaw River at Midland from Dow Chemical Company alone were reduced from 2.70 million pounds/day in 1965 to 0.89 million pounds/day in 1972 (MWRC, 1974). Similar data on chlorophyll *a* and total phosphorus are not available from the earlier surveys. However, the observed changes since 1965 do not suggest any strong trends during that period.

The 1965 data set is the most suitable for a more detailed comparison with the 1974-75 survey results. Tables 46-49 show the means and ranges of data for three subdivisions of the bay and for two comparable stations.

Since 1965 chloride concentrations and conductivity appear to have decreased in the inner and middle bay areas by a factor of 2 or 3. Chlorophyll *a* levels seem to have increased slightly throughout the bay. Total phos-

TABLE 44. COMPARISON OF ANNUAL MEAN DATA (WHOLE BAY) FOR 1974 AND 1975

PARAMETER	ANNUAL MEAN ± DEV.	
	1974	1975
Temperature (°C)	13.6 ± 5.9	14.1 ± 6.5
Oxygen, diss. (mg O_2/ℓ)	10.6 ± 1.9	10.6 ± 1.7
Conductivity, spec. (μS/cm)	260 ± 72	248 ± 54
Chloride, filt. (mg Cl/ℓ)	13.2 ± 9.5	11.2 ± 6.6
pH (s.u.)	8.45 ± .40	8.5 ± .3
Alkalinity, tot. (mg $CaCO_3$/ℓ)	92 ± 15	92 ± 16
Secchi disc depth (m)	1.8 ± 1.5	2.1 ± 1.5
Chlorophyll *a*, non-filt. (μg chl. *a*/ℓ)	15.7 ± 14.3	11.9 ± 13.4
Carbon, unfilt. org. (mg C/ℓ)	5.6 ± 3.6	5.1 ± 2.4
Carbon, filt. org. (mg C/ℓ)	4.4 ± 2.0	4.3 ± 1.9
Solids, unfilt. tot. (mg/ℓ)	127.4 ± 67.6	182.5 ± 53.2
Silicate-silicon, filt. reac. (mg SiO_2/ℓ)	.99 ± .55	.55 ± .63
Ammonia, filt. (mg N/ℓ)	.037 ± .076	.018 ± .020
Nitrate + nitrite-nitrogen, filt. (mg N/ℓ)	.295 ± .344	.225 ± .214
Nitrogen, unfilt. Kjel. (mg N/ℓ)	.326 ± .233	.33 ± .22
Nitrogen, tot. (mg N/ℓ)	.544 ± .258	.557 ± .343
Phosphate-phosphorus, filt. reac. (mg P/ℓ)	.006 ± .009	.002 ± .003
Phosphorus, filt. tot. (mg P/ℓ)	.006 ± .009	.007 ± .004
Phosphorus, unfilt. tot. (mg P/ℓ)	.025 ± .027	.020 ± .021
Sodium, unfilt. (mg Na/ℓ)	7.0 ± 5.5	-
Potassium, unfilt. (mg K/ℓ)	1.4 ± .6	-
Calcium, unfilt. (mg Ca/ℓ)	37.0 ± 11.5	-
Magnesium, unfilt. (mg Mg/ℓ)	9.1 ± 2.6	-

TABLE 45. WATER QUALITY CHANGES IN SAGINAW BAY DURING JULY-OCTOBER, 1935-1975

PARAMETER	LOCATION†			YEAR	DATA SOURCE*
	SAGINAW RIVER	INNER AND MIDDLE BAY (SEGMENTS 1,2,3)	OUTER BAY (SEGMENTS 4,5)		
Chloride (mg/ℓ)	50-300	25-40	10	1935-36	1
	280	60	11	1956	2
	170	47	8	1965	3
	---	---	2-20	1966	4
	---	---	10	1970	5
	99.3	17.9	7.9	1974	6
	62.9	16.9	7.9	1975	6
Chlorophyll *a* (μg/ℓ)	18.0	20.7	2.5	1965	3
	41.7	17.2	5.4	1974	6
	34.7	21.3	7.2	1975	6
Total Phosphorus (mg/ℓ)	---	.041	.018	1956	2
	.17	.01 - .07	.01-.17	1965	3
	---	---	.01-.03	1971	7
	.221	.038	.011	1974	6
	.237	.037	.013	1975	6

*1-Mich. Stream Cont. Comm. (1937)
2-Beeton, et al. (1967)
3-U.S. Fed. Water Poll. Contr. Adm. (1969)
4-U.S. Lake Survey Ctr. (1966)
5-Schelske and Roth (1973)
6-Present report (1977)
7-Canadian Cetr. for Inland Waters (1971)

†One meter samples only.

TABLE 46. COMPARISON OF 1965 (FWPCA) and 1974-75 (EPA) DATA* FOR INNER SAGINAW BAY

PARAMETER	1965 - (4 STA.)		1974 - SEGMENT 1 (13 STA.)		1975 - SEGMENT 1 (5 STA.)	
	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
Temperature, °C	15.5	3.5 - 22.0	19.1	11.0 - 24.0	18.9	10.6 - 26.8
Dissolved Oxygen	9.8	6.2 - 12.7	9.96	6.8 - 11.9	9.97	6.0 - 13.5
pH	8.0	7.1 - 8.5	8.78	8.2 - 9.2	8.72	7.6 - 9.4
Conductivity, µS/cm	430	270 - 720	294	227 - 843	308	230 - 492
Chloride (f. Cl)	62	25 - 130	20.8	10.0 - 49.0	20.1	11.0 - 44.0
Ammonia-N (f. NH_3-N)	.36	.10 - 1.60	.039	.009 - .138	.039	.003 - .153
Nitrate + Nitrite-N (f. NO_3 + NO_2-N)	.3	<.1 - 1.2	.091	.050 - .300	.168	.050 - 1.10
Total N (tot. N)	-	-	.664	.330 - 1.43	.968	.340 - 2.74
Dissolved P (f. tot. P)	-	<.01 - .07	.008	.002 - .020	.017	.004 - .083
Total P (u. tot. P)	-	<.01 - .17	.048	.004 - .116	.060	.017 - .160
Calcium (u. Ca)	49	26 - 72	38.8	31.0 - 53.0	-	-
Magnesium (u. Mg)	16	10 - 33	10.3	8.0 - 14.0	-	-
Sodium (u. Na)	20	9 - 31	11.7	5.0 - 50.0	-	-
Potassium (u. K)	5.5	2.3 - 9.5	1.7	1.2 - [illegible]	-	-
Chlorophyll *a*, µg/ℓ (n-f. chl. *a*)	24.4	-	33.5	8.0 - 68.3	34.4	5.7 - 87.9

* All values in mg/ℓ unless otherwise indicated.

TABLE 47. COMPARISON OF 1965 (FWPCA) AND 1974-75 (EPA) DATA* FOR MIDDLE SAGINAW BAY

PARAMETER	1965 - (9 STA.)		1974 - SEGMENTS 2 & 3 (23 STA.)		1975 - SEGMENTS 2 & 3 (13 STA.)	
	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
Temperature, °C	15.5	3.5 - 21.5	19.3	10.0 - 26.4	18.9	10.2 - 26.9
Dissolved Oxygen	9.8	8.0 - 12.6	9.88	5.1 - 12.2	9.8	6.3 - 12.9
pH	8.0	7.1 - 8.4	8.7	7.8 - 9.2	8.7	8.1 - 9.4
Conductivity, μS/cm	324	180 - 540	258	169 - 321	253	209 - 367
Chloride (f. Cl)	36	4 - 100	14.1	3.0 - 46.0	12.5	6.0 - 28.0
Ammonia-N (f. NH_3-N)	.19	<.05 - .94	.044	.008 - .239	.007	.003 - .023
Nitrate + Nitrite-N (f. NO_3 + NO_2-N)	.1	<.1 - 1.0	.099	.050 - .400	.077	.050 - .300
Total N (tot. N)	.46	<.1 - 1.0	.623	.280 - 2.250	.625	.180 - 2.70
Dissolved P (f. tot. P)	-	<.01 - .07	.007	.002 - .033	.007	.002 - .021
Total P (u. tot. P)	-	<.01 - .07	.031	.004 - .069	.029	.002 - .078
Calcium (u. Ca)	41	27 -54	37.1	30.0 - 48.0	-	-
Magnesium (u. Mg)	14	8 - 25	9.6	8.0 - 12.0	-	-
Sodium (u. Na)	15	3 - 37	8.5	5.0 - 13.0	-	-
Potassium (u. K)	4.0	.9 - 5.5	1.5	1.2 - 2.1	-	-
Chlorophyll *a*, μg/ℓ (n-f. chl. *a*)	16.9	-	24.6	2.3 - 58.5	19.4	1.8 - 68.5

* All values in mg/ℓ unless otherwise indicated.

TABLE 48. COMPARISON OF 1965 (FWPCA) AND 1974-75 (EPA) DATA* FOR OUTER SAGINAW BAY

PARAMETER	1965 - (10 STA.)		1974 - SEGMENTS 4 & 5 (19 STA.)		1975 - SEGMENTS 4 & 5 (14 STA.)	
	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
Temperature, °C	13.0	3.0 - 20.0	17.8	7.0 - 29.0	17.7	10.6 - 25.1
Dissolved Oxygen	10.3	8.2 - 12.5	9.9	8.3 - 11.6	9.9	7.4 - 12.8
pH	7.9	6.9 - 8.3	8.5	7.9 - 9.1	8.5	8.0 - 9.1
Conductivity, μS/cm	210	120 - 340	219	186 - 288	219	192 - 323
Chloride (f. Cl)	8	4 -18	8.2	3.0 - 21.0	7.9	5.0 - 21.0
Ammonia-N (f. NH_3-N)	.14	<.05 - .49	.031	.005 - .128	.013	.003 - .034
Nitrate + Nitrite-N (f. NO_3 + NO_2-N)	.2	<.1 - .5	.161	.050 - .300	.147	.050 - .200
Total N (tot. N)	.47	<.1 - 1.38	.466	.190 - .940	.422	.180 - 2.48
Dissolved P (f. tot. P)	-	<.01 - .13	.004	.002 - .014	.005	.002 - .025
Total P (u. tot. P)	-	<.01 - .17	.012	.002 - .050	.012	.002 - .071
Calcium (u. Ca)	27	22 - 35	29.2	24 - 36.0	-	-
Magnesium (u. Mg)	11	8 - 19	7.6	7.0 - 10.0	-	-
Sodium (u. Na)	4	3 - 7	3.7	3.0 - 8.0	-	-
Potassium (u. K)	1.5	.9 - 2.2	.9	0.7 - 1.4	-	-
Chlorophyll *a*, μg/ℓ (n-f. chl. *a*)	2.5	-	7.1	0.4 - 57.4	7.2	0.9 - 38.8

* All values in mg/ℓ unless otherwise indicated.

TABLE 49. COMPARISON OF 1965 (FWPCA) AND 1974-75 (EPA) DATA* FOR TWO SIMILAR LOCATIONS IN INNER SAGINAW BAY

Parameter	1965 Sta. X100	1974-75 Sta. 9	1965 Sta. H232	1974-75 Sta. 24
Temperature, °C	17.0	16.3	15.5	15.5
Dissolved Oxygen	8.0	8.3	9.8	9.3
pH	7.7	8.3	8.0	8.7
Conductivity, μS/cm	820	525	320	273
Chloride (f. Cl)	170	59.1	35	13.5
Ammonia-N (f. NH_3-N)	.55	.211	.16	.045
Nitrate + Nitrite-N (f. NO_3 + NO_2-N)	.74	.528	.20	.318
Total N (tot. N)	1.53	1.475	.48	.424
Dissolved P (f. tot. P)	.10	.068	-	.004
Total P (u. tot. P)	.17	.163	-	.028
Calcium (u. Ca)	87	-	40	34†
Magnesium (u. Mg)	26	25†	13	8†
Sodium (u. Na)	52	35†	13	4†
Potassium (u. K)	13.6	4.4†	3.6	1.1†
Chlorophyll *a*, μg/ℓ (n-f. chl. *a*)	-	31.8	18.2	18.7

*Mean values in mg/ℓ, except as indicated.
†1974 data only.

phorus data are inconclusive, as are mean values for the various forms of nitrogen. Concentrations of major metals have decreased throughout the bay since 1965; the percentage decrease was least for calcium and greatest for potassium.

STATISTICAL RELATIONSHIPS

Correlation analyses and multiple regression analyses were undertaken to define statistical relationships among the chemical and physical parameters studied. First, simple Pearson correlation coefficients (Pearson's r), which represent the degree of association between two variables, were computed for all combinations of parameters. The sample matrix of Pearson's r, shown in Table 39, includes only those values significant at the 99% level. Among the relationships between parameters, those of chloride, Secchi disc depth and various nutrients with chlorophyll *a* are informative since chlorophyll *a* has long been used as an indicator of algal biomass. Although the correlations alone do not establish causality, they still should reflect the dependence of algal biomass on "limiting" nutrients, including nitrogen and phosphorus species. To that extent the statistical results may suggest cause-and-effect relationships that warrant closer study.

Since the number of samples (parameter pairs) used in the correlations was different for each cruise, an attempt was made to normalize Pearson's r by using the Z transformation with each standard deviation. In Figures 49-53 each value of Pearson's r, plotted against time, has been normalized for variation in sample numbers by the use of the Z transformation divided by its standard deviation (Zr/Sz). Thus, the significant values of Zr/Sz can be considered as corrected for variations in sample numbers.

The resulting plot of the correlation of chlorophyll *a* with temperature is shown in Figure 49. In segments 1, 4 and 5, significant correlations are shown for some cruises. This is due to the fact that warmer waters and/or greater runoff, particularly in the spring, were associated with higher primary production both in the inner and outer bay.

Correlations of chlorophyll *a* with chlorides were significant mainly during the spring and fall and especially in the outer bay (Figure 50). While chloride itself has little importance as a plant nutrient, it serves to label Saginaw River water which is enriched with respect to many nutrients. Some of these may stimulate algal production in the outer bay.

Secchi disc depth was correlated sometimes with chlorophyll *a* (Figure 51) in part because some reduction in water transparency is caused by algal cells, especially during periodic blooms. However, it is apparent that turbidity or decreased Secchi depth is not strongly correlated with algal population (i.e., chlorophyll), particularly in segment 1 where sediment loadings from the Saginaw River strongly affect water clarity.

In all areas but segment 3 chlorophyll *a* and total nitrogen levels appear to be correlated best (Figure 52) during three separate periods in the spring, summer and fall. These may correspond to bloom situations when the rates of either nitrogen input or fixation (by blue-green algae) were relatively high. However, this pattern was less noticeable during 1974 than in 1975.

The correlations of chlorophyll *a* with total phosphorus (Figure 53) were remarkably similar to those with chloride (Figure 49). This suggests that the phosphorus content of Saginaw River water (labelled by chloride) stimulates algal production throughout the bay.

In all cases the correlation of chlorophyll *a* with the above parameters was probably least variable in segment 3. This may be due in part to the stabilizing effect of nutrient loadings other than those from Saginaw River waters. This has already been mentioned in relation to total carbon levels in segment 3. Secondly, there is notable difference in these correlations between 1974 and 1975, which suggests a variation in cause and effect relationships with climatic or other circumstances.

The results of multiple regression analysis shown in Tables 40 and 41 indicate that chlorophyll *a* levels (as the dependent variables) were largely predictable on the basis of "particulate" phosphorus levels; the latter data were calculated by subtracting filtered total P from unfiltered total P. Predictability was improved only slightly by addition of f. reac. phosphate and f. nitrate + nitrite-N data to the equation. This was especially true in 1974. Such strong correlations between chlorophyll *a* and particulate forms of phosphours and nitrogen are to be expected since these are important constituents of phytoplankton. Soluble forms of these nutrients, however, may vary inversely with chlorophyll concentration since they tend to be depleted from bay waters during algal blooms.

In Table 42 similar results are presented for each segment. These show that chlorophyll *a* varies primarily as a function of total or particulate phosphorus. Secondarily important are dissolved forms of nitrogen and phosphorus as well as total nitrogen. On the whole, predictability of chlorophyll *a* levels from nutrient data appeared to be most reliable in the outer bay, segments 4 and 5.

RELATION TO WATER QUALITY STANDARDS

Results for only a few of the parameters surveyed can be considered in the context of EPA and Michigan standards for public water supplies. Current standards are shown in Table 50.

Although a few ammonia values recorded in the Saginaw River and at segment 1 stations (up to 2.14 mg N/ℓ) exceeded the EPA standards, nearly all mean values for each station and segment were well below 0.5 mg N/ℓ. Most segment means were less than 0.05 mg N/ℓ. No single value for nitrate + nitrite reached 10 mg N/ℓ; the highest value was 3.6 mg N/ℓ. Most mean values for stations and segments were below 0.5 mg N/ℓ. All chloride values (maximum, 185 mg Cl/ℓ) were below the EPA standard of 250 mg/ℓ. Annual means for four stations in the Saginaw River mouth exceeded the Michigan standard of 50 mg Cl/ℓ (monthly average). However, no quarterly mean for segment 1 was

TABLE 50. WATER QUALITY STANDARDS FOR PUBLIC WATER SUPPLIES*

Parameter	EPA Standard (1972)	Michigan Standard for Great Lakes (1977)
Ammonia - N	0.5	---
Chloride	250.0	50.0**
Dissolved Oxygen	---	6.0
Nitrate + Nitrite	10.0	---
pH	5.0 - 9.0	6.5 - 8.8

* All values except pH in mg/ℓ.
** Based on monthly average.

greater than 26.4 mg Cl/ℓ. A number of dissolved oxygen values in the Saginaw River were less than the Michigan standard of 6 mg O_2/ℓ; the minimum was 2.7. However, the lowest mean values were 6.7 mg O_2/ℓ for a river station (54) and 9.4 mg O_2/ℓ for segment 3. Some pH values in all segments and in the river exceeded the upper limits of 9.0 (Michigan) and 8.8 (EPA standard). The full range of pH recorded during both years was 6.88 - 9.58. Five station mean values were slightly above 8.8. Segment means, except in two quarters, were below the EPA upper limit of 8.8.

The standards for nutrients (other than nitrate + nitrite) required to protect water supplies, wildlife and recreational waters are not defined quantitatively. Michigan regulations state:

> Rule 1060. Nutrients originating from domestic, industrial, municipal or domestic animal sources shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached and floating plants, fungi or bacteria which are or may become injurious to the designated uses of the waters of the state (MWRC, 1974).

It is clear that current levels of phosphorus, nitrogen and other nutrients in Saginaw Bay do stimulate rich algal growths, but whether to an "injurious" degree remains to be established.

Sawyer (1947) has defined critical springtime levels of inorganic nitrogen and phosphorus (reactive phosphates) that he considered sufficient to cause algal blooms and which therefore characterize eutrophic waters. These thresholds are:

Inorganic N -- 0.300 mg N/ℓ
Inorganic P -- 0.010 mg P/ℓ

Yearly averages of inorganic nitrogen (nitrate, nitrite and ammonia) in Saginaw Bay indicate that segments 1, 2 and 3 were above Sawyer's critcial concentration of 0.300 mg N/ℓ. On the basis of yearly averages of inorganic reactive phosphates (orthophosphates), only segment 1 (1974) was above the critical level of 0.010 mg P/ℓ. However, on the basis of 2nd quarter concentrations, both segments 1 and 3 were above the critical level. Segments 4 and 5 were well below it.

Clearly, these values alone are not reliable as indicators of trophic condition in Saginaw Bay. Frequently, the lowest levels of reactive phosphate in the inner bay, for instance, may simply reflect algal uptake during blooms rather than a decrease in the input rate. Turnover rates of available nitrogen and phosphorus are the crucial factors not apparent in these results.

Cooperative Studies

Remote Sensing --

These results also have been used in a study conducted by Bendix Aerospace Systems Division in Ann Arbor, Michigan. The project, entitled "Application of Landsat to the Surveillance and Control of Lake Eutrophication in the Great Lakes Basin", was supported by Contract NAS 5-20942 from the National Aeronautics and Space Administration (NASA). The objectives of that part of the study related to Saginaw Bay were to use satellite multispectral data to estimate levels of various water quality factors and to map their distribution throughout the bay. Thus, Landsat surveillance was intended to supplement mapping of nutrient distributions based on conventional sampling from ships. Data from the bi-weekly cruises, which were scheduled to coincide with Landsat passes over Saginaw Bay, were correlated with reflectance measurements recorded by satellite sensors in four regions of the visible to near-infrared spectrum. This approach was designed to show empirical relationships between remote and direct measurements that could be used to predict concentrations in unsampled areas.

The satellite data that Bendix chose to process were recorded on two occasions, June 3, 1974 and July 31, 1975, coinciding with cruises 8 and 25, respectively (Table 43). In applying a step-wise linear regression analysis to the data, the water quality measurements were each considered as dependent variables; Landsat reflectance measurements were regressed against these as independent variables. The results indicate which sensor band, band ratio or combination of bands was most useful for predicting levels of each water quality parameter. Correlation coefficients and prediction accuracy were evaluated in each case. The processed Landsat data were used finally to generate a color-coded image or map of water quality categories throughout the bay. Examples are shown in Figures 54 and 55.

Results of the Bendix study suggest that such water quality maps based on calibrated satellite data can be used with fair reliability to estimate ranges of concentration for certain parameters, even for those variables (e.g., total phosphorus, chloride) which are not directly detectable by remote sensors. This is true because water masses with a varying content of Saginaw River water are enriched correspondingly with nutrients and salts. The same river water is characterized also by its color and particle content, which are markedly different from those of Lake Huron water. As a result, river water in various stages of dilution can be identified by visible characteristics which are correlated with other conservative but invisible features of water quality.

However, the results showed that relationships between turbidity and other variables, such as chloride or temperature, are strictly empirical and are subject to change, perhaps even on a daily basis. Moreover, the Landsat data, even on apparently clear days, are affected by atmospheric losses that may differ in each spectral band. In summary, it is apparent that regular Landsat mapping of water quality in the bay is feasible with the following provisions: that sampling is conducted within a few hours of Landsat passage; that such concurrent measurements are used to "re-calibrate" the satellite data on each occasion; that the errors of estimation for each parameter (based on comparison of actual and predicted values) are within acceptable limits. The advantages of using Landsat monitoring, as an adjunct to conventional point-sampling are that is provides an economical basis for extrapolating water quality parameters from point samples to unsampled areas, and it provides a synoptic view of water mass boundaries that no reasonable amount of point sampling could duplicate.

The methodologies, results and conclusions of this study are discussed in more detail elsewhere (Rogers, et al., 1975a; Rogers, et al, 1975b; Rogers, et al., 1976).

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